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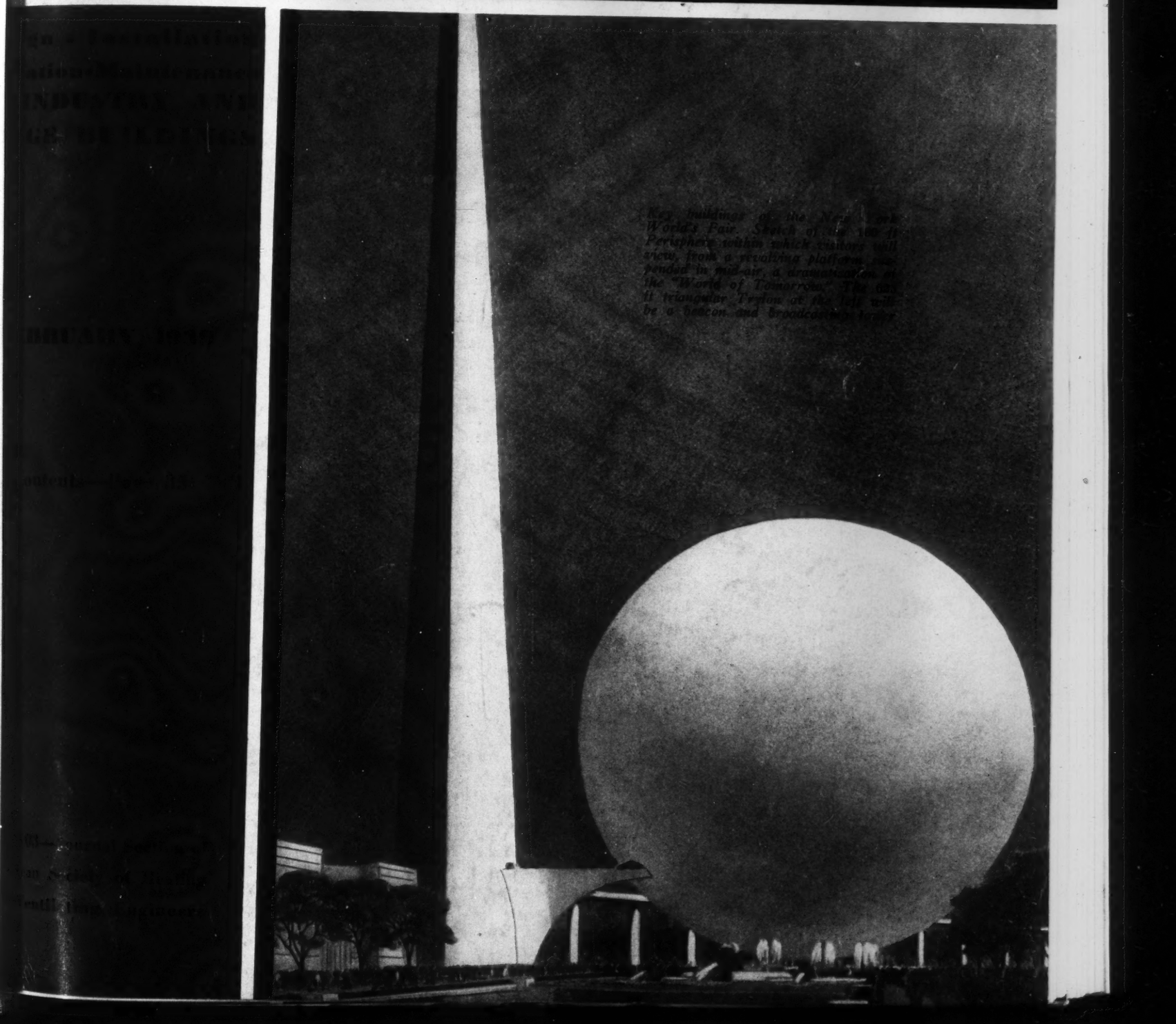
Heating · Piping and Air Conditioning



Key buildings of the New York World's Fair. Sketch of the 350-ft Perisphere within which visitors will view, from a revolving platform suspended in mid-air, a dramatization of the "World of Tomorrow." The 610-ft triangular Trylon at the left will be a beacon and broadcasting tower

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The Editor's Page

■ **Physiology for the engineer** was discussed by Howard W. Haggard of Yale University in a lecture delivered before the annual meeting of the ASME in December.[1] He pointed out that more and more the engineer deals with the reactions of human beings. He asked, "Is it not possible that in designing these machines, these conveniences, these artificial environments, the engineer in suiting them to human needs has been guided only by rules of thumb of physiology as incomplete as is the simple dogmatic knowledge with which a public, untrained in true engineering, has learned to use these machines?" If the engineer is going to create environments or situations affecting human beings, then physiology becomes a major element in his problems. A primary physiological axiom for engineers is that the body operates as a whole, and that if in any way a single part of a single function is affected, every other part and every other function is affected. As examples of engineering achievements to illustrate his point he chose air conditioning and modern artificial lighting, both of which have changed the human environment. . . . He discussed the temperature regulating system of the human body, how the heat to keep the body warm is developed and how it is dissipated, and he cited a complicating factor in the co-ordination of bodily functions. For example, when the vessels of the skin expand, the resistance to the flow of blood is diminished, since by dilatation of the vessels in the skin the channel for the flow of the fluid is increased. The pressure, therefore, tends to fall and it in turn must be regulated. To hold up the pressure, arteries are constricted in parts of the body other than the skin, a compensatory constriction mainly in the digestive organs. Consequently digestion may be slowed; in extreme cases it is stopped. To help hold up the pressure of the blood diverted to the enormous channels in the skin, the heart must pump a greater volume for the circulation. In hot surroundings the heart in a man at rest may be doing as much work as it would in the same man performing violent exertion in cool surroundings. Notice the deaths, during heat waves, of invalids with damaged hearts. Heat to them is the same as the exertion which they are incapable of making. It correspondingly limits the capabilities of the man with the normal heart. . . . The speaker mentioned that he sees in air conditioning the great advantages of comfort and the conservation of capabilities that may be thus directed to productive work, and that he also sees a drawback in the refinements of air conditioning. Too close control of conditions is disastrous in physiological practice because the body responds only to stimulation and when stimulation is removed, stagnation results and the human machine does what the inanimate machine never does—it goes to sleep and deteriorates functionally, he said. The temperature regulating mechanism of the body at rest operates best when there are slight but definite and continual changes in the cooling power of the air, he said.

[1]See *Mechanical Engineering*, January, 1939, pp. 8-12.

■ **The 50th anniversary** of the Heating, Piping and Air Conditioning Contractors National Association is to be celebrated at the association's convention at the Drake Hotel, Chicago, May 31-June 2. The idea of a national association of master steam and hot water fitters was conceived a half century ago on April 12, 1889, the original incorporators being John Davis, Polhemus S. Hudson, Foster W. Lamb, Chas. H. Simmons, Herman Kroeschell, Samuel I. Pope, Albert Galloway, Leon H. Prentice, and George H. Reynolds. . . . The association is making an intensive effort to find all those still living who attended its first convention.

■ **Carl A. Ostling** became vice president in charge of production of Carrier Corp. last month; he was formerly in charge of industrial engineering of General Motors' Pontiac Division. Edward T. Murphy, vice president in charge of the Carrier central district area, became vice president in charge of marketing, and James A. Bentley, vice president and head of the international division, became vice president in charge of finance. . . . The changes followed the resignation of L. R. Boulware, vice president and general manager of Carrier since 1936.

■ **In a discussion** of long range factors in the building industries by W. C. Bober of Johns-Manville, published in "Trusts and Estates", the author points out a rather interesting thing about *time lag* in the matter of population trend that is extremely important to the construction industry but is by no means widely understood. Just as our declining population growth is casting its shadow before, so our very rapid population growth in past decades is "still casting its rays on the construction industry" and will continue to do so much longer than is generally realized. . . . Selecting 1924 as a starting point, because thereafter there was a basic change in population trend, he shows that the 2,500,000 people born then will "roll down through the decades" similar to the moving crest of a river flood. In 1940 the children born in 1924 will be ready to look for jobs. They will be 25 years of age in 1949 and therefore the greatest number of young people that have ever yet or will ever again be looking for homes will do so approximately in 1949. In that year the crest of the flood will therefore have reached the residential construction industry.

■ **Stoker and boiler** manufacturers, bituminous coal interests and smoke prevention engineers are combining their efforts in a field survey of over 100 actual stoker installations in all sizes and types of boilers, the purpose being to establish authoritative data upon which combustion space requirements can be determined. The stoker and bituminous coal industries favor higher heat release values, and smoke inspectors (on the other hand) lean to the lower values. . . . It is believed that the survey will establish facts in regard to the relation of setting heights and combustion space to the amount of smoke produced, which will avoid disagreement.

■ **J. L. Shrode,** president and founder of the Alco Valve Co., died December 31 at the age of 58. Mr. Shrode invented and patented an automatic constant pressure type expansion valve in 1924 and in 1925 formed the Alco Valve Co. which was incorporated in 1927. . . . On January 1, Russell B. Tewksbury, chairman of the board of Oster Mfg Co., passed away at the age of 79. He was one of the founders of the company in 1893 and one of the five oldest graduates of Princeton University. . . . William Robbins Seigle, chairman of the board of directors, vice president and director of research of Johns-Manville Corp., died at the age of 59 on December 26. With Johns-Manville for nearly 40 years, he began at the bottom as a "jack of all trades" in 1899.

IN THE MODERN OFFICE BUILDING OF JOHNSON WAX

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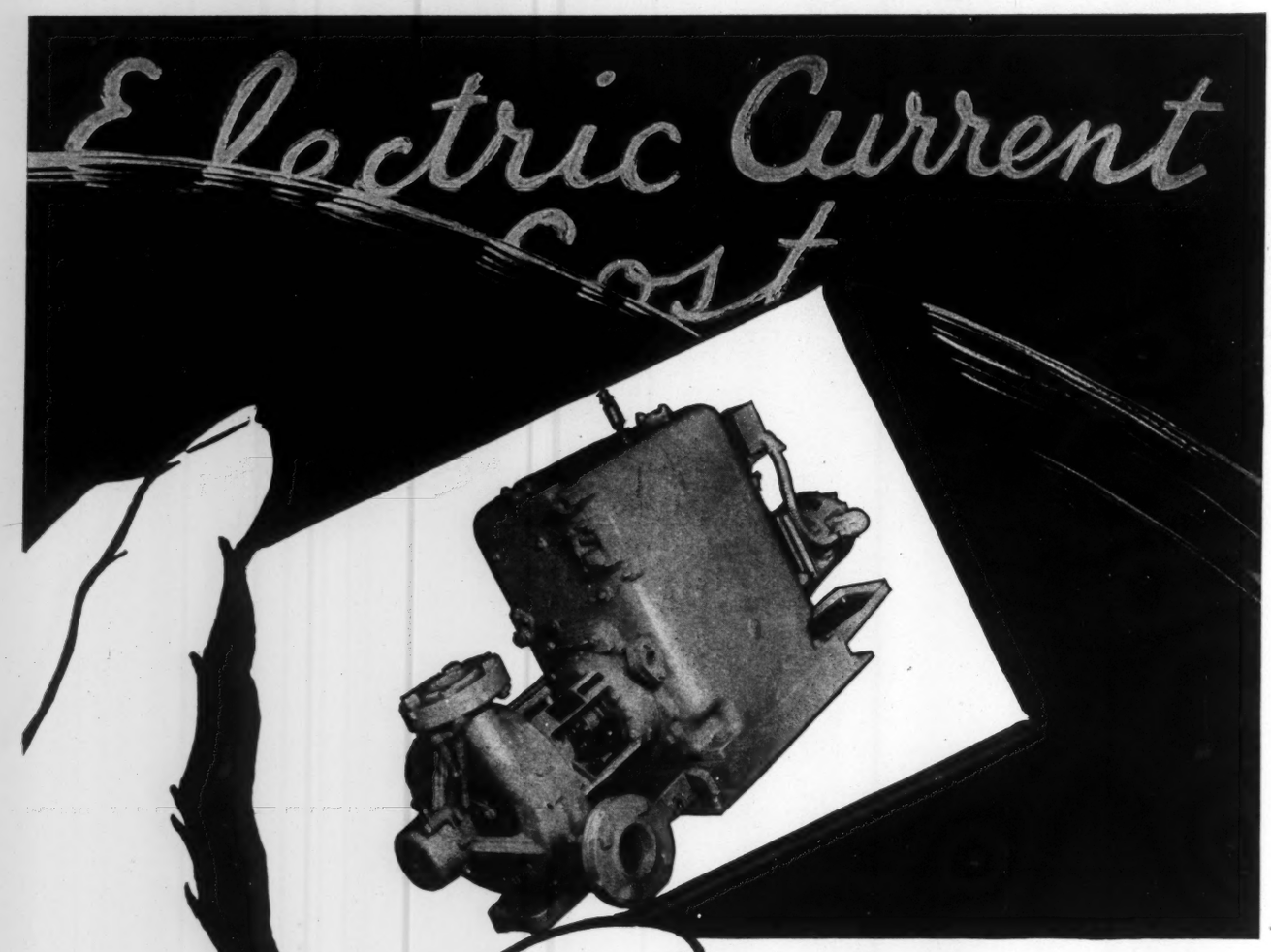

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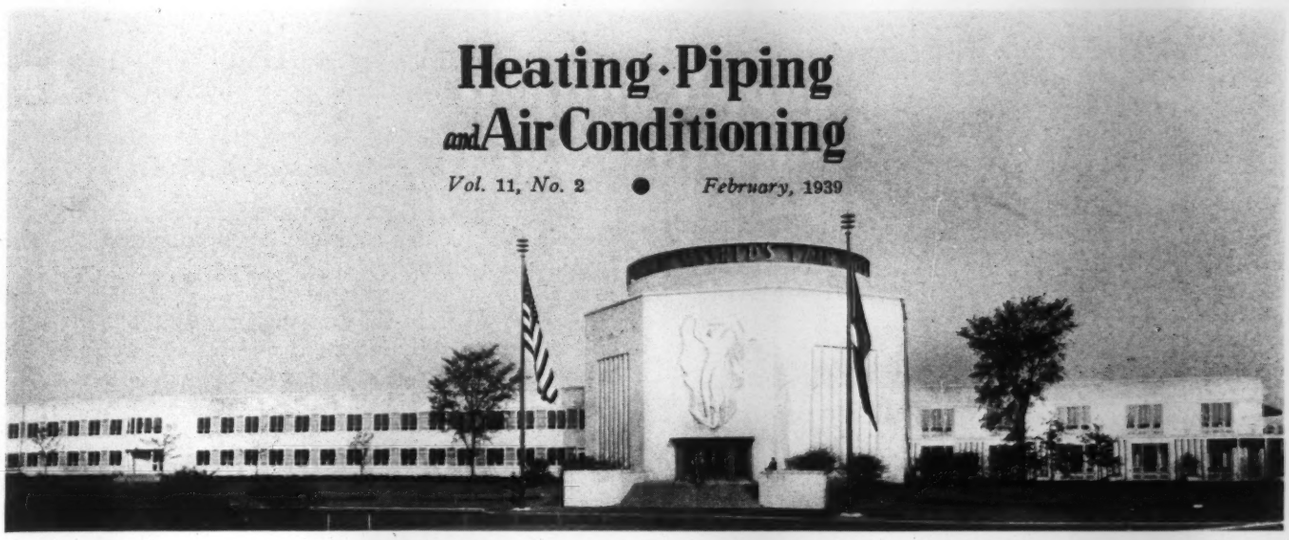
Heating · Piping and Air Conditioning

Vol. 11, *No.* 2 ● *February*, 1939



The air conditioned administration building of the New York World's Fair

Air Conditioning Helps Carry Out Theme of New York World's Fair

THE theme of the New York World's Fair 1939 is "The World of Tomorrow." In carrying out this theme in design and operation it is natural that human comfort should have a very large place and each exhibitor, in order to leave a lasting favorable impression upon the public, is forced to give air conditioning serious consideration.

The Fair Corporation has provided for all-year air conditioning in the administration building, the press and post office building and the Terrace club; summer air conditioning in the Perisphere and the theater and concert hall; heating in the permanent field house, permanent boat house, permanent utility building, three fire, police and hospital buildings, and the employment building; and ventilation in all exhibit buildings (37 in number).

Types of Heating Systems

All heating is designed on the basis of 70 F indoors with 0 F outdoors.

The administration building, the press and post office building and the Terrace club are heated by split systems. Direct radiation is installed throughout these buildings of capacity to provide a 50 F rise in temperature when the outdoor temperature is 0 deg, an additional 20 deg of heating capacity being provided by heating coils in the air handling systems. This split system design permits these buildings to be maintained at comfort conditions when the outdoor temperature is 50 deg and above by means of the air systems. When the outdoor temperature is below 50 deg, the radiator systems are turned on to supplement the air systems. At night, during the winter, these buildings can be maintained at 50 deg with the radiator systems, the air systems being shut down.

This arrangement of heating reduced the size of the radiators and piping and produced a substantial saving in first cost and in operating cost with satisfactory performance.

The air systems are on thermostatic control while the radiators are on hand control. The radiator systems are zoned the same as the air systems so that sun effect can be taken care of without the shaded zones of these buildings being too cool.

The permanent field house is heated by direct steam radiation with a two pipe vacuum system. The permanent boat house is heated by direct fired gas unit heaters. The permanent utility building is heated by steam unit heaters under thermostatic control, with a two pipe vacuum system. The fire, police and hospital buildings are heated with gas steam radiators in each room and direct fired gas unit heaters in the fire apparatus rooms.

By Sanford R. Apt*

"The World of Tomorrow" is the theme of the New York World's Fair 1939, and in carrying it out it is natural that air conditioning for human comfort should have a very large place in the design and operation of the Fair owned buildings and the individual exhibits. Mr. Apt, chief mechanical engineer of the Fair organization, describes the air conditioning, heating, and ventilating problems. . . . Of particular interest is the ventilation and cooling of the Perisphere, a hollow sphere 180 ft in diameter, and the cooling of the rotunda of the administration building (shown above)

*Chief Mechanical Engineer, New York World's Fair 1939, Inc.

Post office, press and promotion building

A careful study was made to determine the most economical fuel for heating. Due to the short life of the Fair buildings and the low gas rate offered by the gas companies serving the Fair area, it was found that gas was the most satisfactory as the first cost of the equipment was less than for other fuel and no fuel storage is necessary—which is a large factor, as the Fair buildings do not have cellars for the storage of solid fuel, and storage tanks for liquid fuel would have presented a difficulty due to bad soil conditions.

Cooling Systems

The summer air conditioning systems are designed on the basis of 95 F dry bulb and 75 F wet bulb outdoors. The administration building, the press and post office building and the Terrace club are designed for 85 F dry bulb and 68 F wet bulb, and the theater and concert hall for 80 F dry bulb and 67 F wet bulb inside conditions. The first three buildings mentioned are two story.

All of the air conditioning systems installed by the Fair Corporation are direct expansion systems. The administration building has five separate refrigeration systems each supplying a separate zone.

The press and post office building and the Terrace club have one refrigeration system each, but have two zones each. These systems are of conventional office design allowing for one person per 85 sq ft of floor space.

The rotunda of the administration building presented a very special case as it is an octagonal hall with a ceiling about 50 ft above the floor. For summer conditions an imaginary ceiling was assumed to exist 10 ft above the floor with the cooling load not extending above this level. The result has proved entirely satisfactory through two summers of use.

The 10 deg cooling in the three buildings was severely criticized as not being adequate, but due to the need for reducing first costs to a minimum it was installed in the administration building and has been found to be very satisfactory—particularly to many visitors to the building who have remarked on the absence of shock when entering and leaving. There were some complaints from the all-day occupants who thought the building was getting too warm in the afternoons, but any who had to go outdoors and return seemed satisfied with the conditions.

The low wet bulb maintained is a great help in producing comfort conditions.

The theater and concert hall will be given a 15 deg maximum differential but will be controlled by the outdoor temperature on a ratio of 2½ to 1 from 70 deg to 80 deg indoor temperature when the outdoor temperature is from 70 deg to 95 deg dry bulb. The seating capacity is 2500.

The Perisphere and Trylon

The Perisphere is a rather interesting experiment from the air conditioning and ventilating standpoint. The building is a hollow sphere 180 ft in diameter supported on eight columns so that the bottom of the sphere is 3 ft above the water in the pool underneath. The columns will be concealed by reflecting surfaces and water jets so it will appear that the sphere is floating on the water jets.

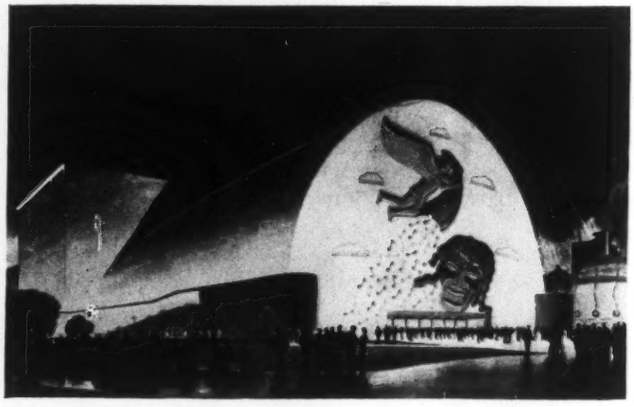
The Perisphere is connected to the Trylon by a bridge whose deck is 60 ft above grade. The Trylon is a three-sided shaft 615 ft high which will serve as the entrance to the Perisphere. Visitors will enter the base of the Trylon and will ride on electric stairways up through the bridge structure to moving platforms which will carry the visitors completely around the interior of the Perisphere. There are two electric stairways and two moving platforms. The platforms are arranged one above the other and an unobstructed view of the interior of the Perisphere may be had from either platform. Part of the show will be below the platform levels and part above the platforms. Each platform will have a capacity of 800 people, which will allow 1600 to be in the Perisphere at one time. The platforms will make one revolution in 6½ minutes.

To air condition the Perisphere completely would require about 500 tons of refrigeration. Due to budget and space limitations, it was impossible to consider this method. It was therefore decided, after considerable study, to maintain conditions on the platforms only, on the theory that there can be no discomfort in the space of the sphere where there are no people.

The plan adopted consists of supplying conditioned air along the base of a railing on each platform; this air will be cooled to a maximum of 10 deg below outside temperature, varying from 0 deg differential at 75 deg outside to 10 deg at 95 deg outside. The conditioned air will be blown at low velocities across the platforms so that little draft will be noticed.

There will also be a supply of outdoor air circulated direct to some of the lighting equipment to remove the

Artist's sketch of the $350,000 air conditioned World's Fair music hall, seating 2500. The auditorium is egg-shaped, without balconies or interior columns, to afford perfect sight lines and acoustics. A dominant feature is a box-like stage house, 80 ft high



Flying far above the Fair. Airplane view of the "World of Tomorrow" plan of the New York World's Fair 1939. Photograph includes all of main exhibit and government areas, also a small section of the amusement area (lower left). Note broad Constitution Mall extending from the Trylon and Perisphere (center) around the oval Lagoon of Nations to the Court of Peace and the Federal group of buildings (lower right). Main artery crossing grounds at lower left is the boulevard intersecting Grand Central Parkway

heat. About 12,000 cfm of conditioned air will be supplied to each platform and 12,000 cfm to the lights, a total of 36,000 cfm. An exhaust system will exhaust 48,000 cfm from the sphere. The additional 12,000 cfm exhausted above that supplied will enter the sphere through the electric stairway passages and doorways. All exhaust air will be taken from points near lighting units and projectors so as to remove the heat at the sources.

About 90 tons of refrigeration is necessary under this scheme to maintain conditions for the occupants, and as the time of occupancy is about 6 minutes, it is believed that a sensation of comfort will be obtained.

As the feature of the Perisphere show is to produce the effect of the visitor being in space above the earth—or in other words of "being up in the air"—it is desirable to produce the effect of the coolness of the upper atmosphere, with corresponding air movement and air purity.

In addition to the cooling of the air and the air movement across the platforms, the air is to be ionized in order to help produce the effect of the upper atmosphere.

All of the air conditioning equipment is to be installed at the bottom between the outer and inner shells of the Perisphere, with ducts carrying the supply and exhaust air between the shells.

All air supplied is outside air, recirculation not being economical due to the high temperatures from the heat of the lighting and projector systems.

The New York City building is designed for year 'round air conditioning. In the summer the refrigeration system will be used to cool the building 7½ deg below outdoor temperature, and in the winter it will be used to freeze an ice skating rink.

At the present writing there is a total of over 50 exhibitors planning to use air conditioning, ranging from a complete year 'round system for an entire building to single room units in rooms in Fair-owned buildings. The largest refrigeration plant has a capacity of 530 tons and the smallest has ½ ton of capacity. All types of air conditioning are being used—indirect chilled water systems, direct expansion systems, silica gel with a refrigeration chilled water supply, and a well water system.

The Fair Corporation has an installed refrigeration capacity of about 700 tons and all exhibitors to date of writing have a capacity of 4032 tons, or a total of 4732 tons of refrigeration capacity.

The larger installations are using evaporative condensers in order to conserve water, although some exhibitors who build such equipment are installing evaporative condensers primarily as part of their exhibits.

Ventilating Systems

The Fair building code requires all exhibit areas to be ventilated at the rate of at least 2 cfm per sq ft of floor. The Fair-owned buildings are designed on the basis of 3 or 4 cfm per sq ft.

In general, attic ventilation is used with exhaust fans installed in the walls or roof as determined by the architecture of each particular building. Standard roof ventilators were not acceptable to the board of design of the Fair as being too high, so it was necessary to design special low ventilators with the fans installed in the attic spaces. In a few buildings it was necessary to install ducts for the ventilation to suit the architectural requirements.

All toilet rooms are ventilated at the rate of 35 cfm per water closet or urinal as required by the building code. This is done by means of separate exhaust systems for the toilet rooms with ceiling grilles above the fixtures to be ventilated. Air is admitted to the toilet rooms through louvered doors.

Water Supply for Air Conditioning

In the fall of 1936, when the designs of the water supply system for the New York World's Fair 1939 were being started, it was necessary to decide on the amount of air conditioning that might be installed in the Fair.

The prediction was made that 50 per cent of the exhibit space in buildings would be air conditioned. This would have produced a large demand for water for condenser use, and if this load were added to the other uses it would have considerably increased the size of the water distribution system. It was therefore decided to use the fire reserve of 9 mgd for air conditioning purposes and to curtail the operation of air conditioning in case of fire. The water is supplied to the Fair from the regular water supply system of the City of New York.

It was decided that the water use would be allocated to exhibitors on the basis of "first come, first served"—except that an exhibitor who planned to use water in excessive quantities would be required to use a recirculating system. The rate for the sale of water was carefully studied so as to produce as large a revenue as possible without unduly curtailing its use for air conditioning purposes.

In addition to the city water supply, application was made to the New York State Water Power and Control Commission for permission to rehabilitate an abandoned well to produce 900 gpm and to drive two or more wells to produce 1500 gpm. This permission was granted provided that all well water be used for air conditioning and be returned to the same stratum from which it is taken (about 150 ft), and provided that there be no interconnections to other supplies. At the present writing, the use of well water is being contemplated by one exhibitor.

Two exhibitors are using lake water for condenser cooling and two are using fountains or cascades for cooling the condenser water.

Insulation of Buildings

Studies were made at the beginning of the design of the buildings to determine the value of insulating the walls and roofs. It was found that for air conditioning for year 'round use it was a considerable saving in first cost to insulate walls and roofs.

The administration building, the press and post office building and the Terrace club are insulated with 4 in. of rock wool. The theater and concert hall and the Perisphere are insulated with 1 in. of board insulation.

The exhibit buildings are insulated, in general, with reflective insulation on the stud sides of both the outside sheathing and the wall board interior surface.

The roofs are insulated, in general, with 1 in. of board insulation and are painted with reflective paint to reflect the heat of the sun.

The New York City building ducts are insulated with some 50,000 sq ft of 1 in. corkboard, and 3500 lineal feet of low temperature piping in sizes up to 8 in. is insulated with cork pipe covering.

List of Air Conditioned Exhibits

It is too early at this writing to give a complete list of the air conditioning installations of exhibitors but the following are the present known ones:

American Radiator Co.
American Tel. & Tel. Co.
American Tobacco Co.
Arkansas
Australia
Beech-Nut Packing Co.
Borden Co.
Bethlehem Steel Co.
Belgium
British Government
Carrier Corp.
Children's World Restaurant
Christian Science
Coca Cola
Consolidated Edison Co.
Continental Baking Co.
Canada
Distilled Spirits
E. I. du Pont de Nemours
Denmark
Eastman Kodak Co.
Electric Utilities Exhibit
Electrified Farm
Firestone Tire and Rubber Co.
Ford Motor Co.
French Government
Florida National Exhibits
Gas Exhibits, Inc.
General Motors Corp.
General Cigar Co.
General Electric Co.
B. F. Goodrich Co.
H. J. Heinz Co.
House of Jewels, Inc.
Household Finance Corp.
Italy
Johns-Manville Corp.
Link-Belt
National Biscuit Co.
National Dairy Products Co.
New Jersey
Rumania
Servel, Inc.
Standard Brands, Inc.
Sweden
Swift and Co.
Triangle Restaurant
United States Steel
Union of Soviet Socialist Republics
Westinghouse Electric & Mfg. Co.
Winter Wonderland
Works Progress Administration
Yale and Towne

There will be refrigeration for process work in the two dairy exhibits and in the meat packing exhibit.

Big du Pont Building Being Air Conditioned

Air conditioning of the du Pont Building in Wilmington, Del., at a cost exceeding $1,000,000 was begun January 23, the du Pont company announces.

Engineers described the job as one of the largest of the kind yet undertaken in the United States. It comprises almost 400,000 sq ft of floor space and will provide all-season temperature and humidity control for the entire block-square, 13 story structure excepting the ground floor, theater and hotel. The hotel's main dining rooms and a large part of the ground floor of the office building are already air conditioned. The theater is closed in summer.

Refrigerating equipment with a total capacity of 1200 tons will be situated in the basement. Cold water will be conveyed to 42 multi-unit conditioners. Ducts in corridors and concealed by false ceilings will carry the conditioned air to offices. Present awnings and window shades are to be replaced with venetian blinds. Seven months are scheduled for the work, which is being handled mainly by local contractors under the general supervision of the company's engineering department.

A country-wide study of air conditioned buildings was made by the du Pont company before deciding on the project. Experimental installations were made in parts of the du Pont building. Conditions in the company's air conditioned Nemours building, completed in 1937, were especially observed.

The evidence was overwhelming in favor of all-season air conditioning. Testimony was that working efficiency is increased, there is less fatigue at the end of the day, and that susceptibility to colds is greatly reduced.

The first section of the du Pont building was erected in 1907. It was not until 1931 that the final section closed the square the building now occupies in Wilmington's business center.

Designing Hot Water Heating Systems

By Erwin L. Weber*

RELATIVELY few practicing engineers are familiar with economical design methods for forced hot water heating systems, especially for the larger installations. This is particularly true in respect to the calculation of pipe sizes, which requires far more skill and time with hot water jobs than with steam heating systems. I have tried in this explanation to bring out those points which I have found are not well known to practicing engineers and contractors, as evidenced by correspondence and inquiries over a period of several years. I have also endeavored to embody the essential information needed to avoid the errors which I have frequently found on plans submitted to me for advice and correction.

The method involves the use of "equalizing non-reflux elbows" on each radiator to adjust the water flow in the circuits.

Notes on the Piping Layout

Estimate the radiation the same as for steam (atmospheric or vacuum) systems. This is permissible in all closed tank systems and in open tank systems it is necessary only to place the expansion tank at least 10 ft above the highest point in the system and connect the expansion line to the return main on the suction side of the pump to permit carrying flow temperatures up to 225 F.

Lay out the piping system in the most direct and convenient manner. Pitch flow mains upward with the direction of flow to eliminate air. Pitch overhead mains *upward* (not downward as in steam systems). Use eccentric reducers pointing up and install air trap on end of main. Provide steam venting valve on vent of air trap to permit exhaust of air, but to avoid passage of steam when flow temperatures are carried above the boiling point. Pitch return mains downward for drainage.

Both flow and return mains may be dropped down below obstructions, or may be run on the ceiling (or even in the attic) and radiators may be supplied by upward or downward risers, as long as the air is relieved either by an air relief trap or by a radiator with an air cock. Underground returns or unsightly returns along baseboards are not required.

Make flow connections to radiators at the top and return connections at the bottom.

I do not believe that overhead systems offer any particular advantage. If it is desired to eliminate air vents from the radiators, a simple method lies in using upfeed mains. Connect the flow inlets to the radiators upward to relieve the air to the flow risers and extend ¼ or ½ in. air relief lines to the attic where they may be gathered and connected to one or more air traps (not the expansion tank).

I do not recommend one pipe systems where more than eight or ten radiators are involved due to the drop in temperature of the water through each successive radiator.

Reversed return or loop systems offer no advantage, it seems to me. They require more pipe and where flow and return mains run parallel on the same ceiling, they are unsightly as the pipes pitch in opposite directions. The belief that such systems are better balanced is ill-founded, according to tests which also have disclosed that under certain conditions a reversal of flow through some of the radiators may take place.

In a properly designed and equalized hot water heating system each unit of radiation must receive its proportional share of water. This ideal condition will naturally produce the same drop in temperature in the water as it passes through the various units and will make the difference in temperature between the flow inlet and the return outlet the same in each unit.

In a circulating system the pressure head produced by the pump, circulator or booster must balance the friction head produced by circulating the proper amount of water to any unit of radiation and back, for each and every unit in the system. From this it is evident that a correctly balanced design involves many tedious calculations, as the complete circuit to each unit of radiation requires individual consideration. Obviously, a wide variety of pipe sizes may be used, depending upon the selected drop in temperature through the systems and the selected friction head to be overcome by the pump.

In average practice the drop in temperature may be taken at 10 F to 20 F for installations up to 10,000 sq ft and 20 F to 30 F for installations from 10,000 to 100,000 sq ft.

The friction head selected should theoretically be such that the sum of the cost of power for pumpage plus the fixed charges on the investment are a minimum per annum. If power is costly it is advisable to use larger pipe sizes with increased initial cost and lower power consumption than if power is cheap. Where high pressure steam turbine driven pumpage is employed and the exhaust steam therefrom can all be used, very small pipe sizes and high friction heads are indicated.

Mr. Weber is a specialist on design of forced hot water heating systems, believes that this type of heating system has many advantages over other methods in both first and operating costs, fuel economy, and temperature control . . . . . He has worked out a design procedure which he uses on his own jobs, developed a method of balancing a hot water heating system using an electro-differential thermometer, and uses "equalizing non-reflux" elbows on radiators to adjust water flow in the various circuits . . . . . He describes his design method here, and presents data for use with it

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*Consulting Engineer.

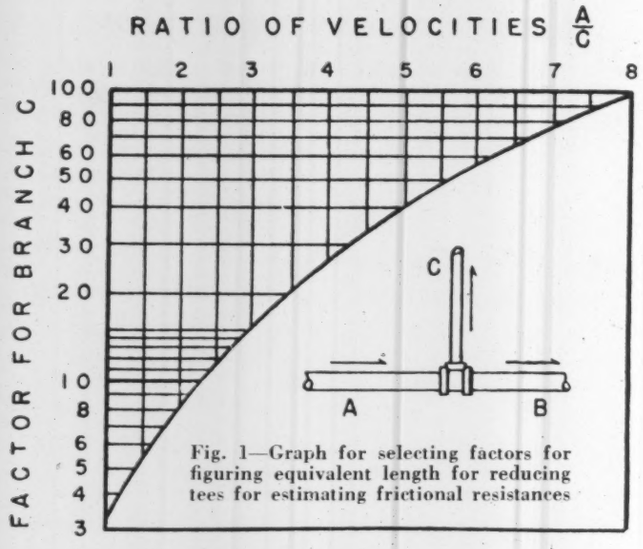

Fig. 1—Graph for selecting factors for figuring equivalent length for reducing tees for estimating frictional resistances

Each problem requires its own solution. For general purposes, the following friction heads (in inches of water) will be found satisfactory:

For small installations (houses, etc.) 20- 72
For moderate installations (750 to 2000 sq ft) 72-180
For medium installations (2000 to 10,000 sq ft) 180-360
For larger installations (10,000 to 100,000 sq ft) 360-900

In general, it is good practice to design with a high drop at the beginning and low drop at the end of each main.

To avoid noise do not use velocities of water higher than 10 fps (except in underground transmission systems and places where noises are not objectionable). To avoid clogging, do not use pipes smaller than ½ in. diameter, except for air relief lines.

To estimate the equivalent length of a circuit, add to the actual length of the pipe the equivalent length for fittings, etc., as given in Table 1. The nominal diameter of the pipe in *inches* is multiplied by the factor given, and the product is the equivalent length of pipe in *feet* to be added to the circuit.

The factors given for branches from tees are based upon tees with all outlets of the same size. For reducing tees, the factor is a function of the ratio of velocities *A* to *C*, according to Fig. 1. Thus, if the ratio of velocities is 3, use a factor 15. The friction in runs *A* and *B* is practically negligible.

The frictional resistance, velocity, etc., may be determined by Fig. 2, which shows the relations between the total Btu per hr transmitted (based upon a 20 F drop in temperature), pipe sizes, velocities of water, and

Table 1—Factors for Figuring Equivalent Length of Valves and Fittings

Boiler	6.0
Radiator	6.0
90 deg elbow	2.0
45 deg elbow	1.5
90 deg long turn elbow	1.0
Open gate valve	1.0
Open globe valve	24.0
Angle radiator valve	4.0
In branches from tees with	
25 per cent water to branch	32.0
33⅓ per cent water to branch	18.0
50 per cent water to branch	8.0
100 per cent water to branch	3.5
Equalizing non-reflux elbow, to be used at the return end of each unit of radiation for the final adjustment and to produce the necessary restriction of flow, including the effects of gravity circulation	14 to infinity

Note—Multiply the nominal diameter of the pipe in inches by the factor given above. The product is the equivalent length of pipe in *feet* to be added to the circuit.

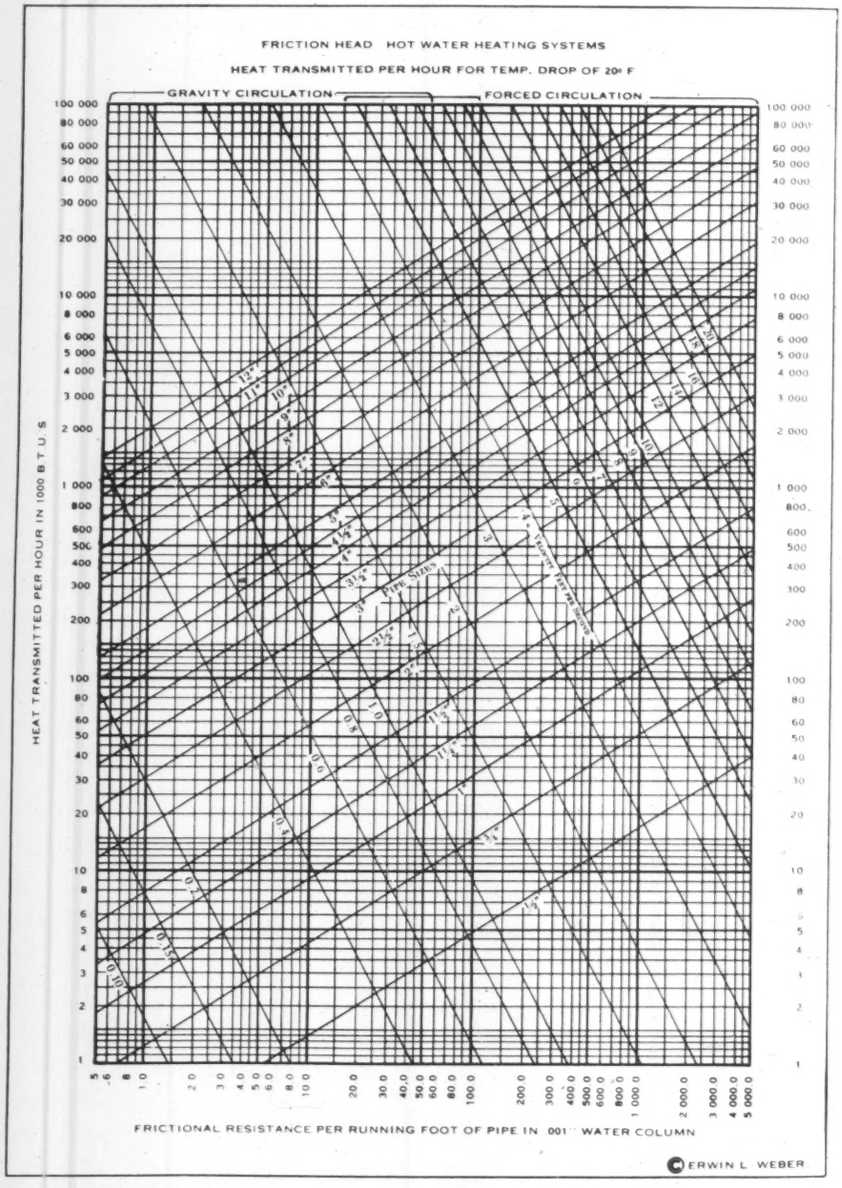
FRICTION HEAD HOT WATER HEATING SYSTEMS
HEAT TRANSMITTED PER HOUR FOR TEMP. DROP OF 20° F
GRAVITY CIRCULATION
FORCED CIRCULATION
HEAT TRANSMITTED PER HOUR IN 1000 B T U S
FRICTIONAL RESISTANCE PER RUNNING FOOT OF PIPE IN .001" WATER COLUMN
ERWIN L. WEBER

Fig. 2—Relation between total Btu per hr transmitted, pipe sizes, water velocities, and frictional resistance

Table 2—Design Data Based Upon a Drop in Temperature of 20 F and for Equivalent Direct Radiation, a Transmission Rate of 240 Btu per Sq Ft Per Hr

Pipe Sizes, In.			Capacity of Pump, Gpm	Capacity of Exp. Tank Gal	Heat Transfer in MBtu (1000 Btu)	Sq Ft of Equivalent Direct Radiation	Size of Mains and Rad. Connections, In.		
Expansion Line	Overflow Line	Vent Line					Near Boiler	Middle of Run	At End of Run
¾	¾	½	3	10	4	15	½	½	½
¾	¾	½	3	10	5	20	½	½	½
¾	¾	½	3	10	8	30	½	½	¾
¾	¾	½	3	10	13	50	½	½	¾
¾	¾	½	3	10	20	75	½	¾	¾
¾	¾	½	3	10	25	100	½	¾	1
¾	¾	½	5	10	38	150	½	¾	1
¾	¾	½	6	10	50	200	¾	1	1¼
¾	¾	½	8	10	75	300	¾	1	1½
¾	¾	½	12	12	125	500	1	1¼	2
1	1	½	20	20	190	750	1	1¼	2
1	1	½	25	25	250	1,000	1¼	1½	2½
1	1¼	¾	40	32	375	1,500	1½	2	2½
1	1¼	¾	50	42	500	2,000	1½	2	2½
1	1¼	¾	75	60	750	3,000	2	2½	3
1	1¼	¾	125	100	1,250	5,000	2	2½	3½
1	1¼	¾	185	150	1,875	7,500	2½	3	4
1¼	1½	1	250	220	2,500	10,000	2½	3½	5
1¼	1½	1	375	315	3,750	15,000	3	4	5
1½	2	1¼	500	420	5,000	20,000	3½	4	6
1½	2	1¼	720	650	7,500	30,000	4	5	6
2	2½	1¼	1,200	1,000	12,500	50,000	5	6	8
2½	3	1¼	1,800	1,500	18,750	75,000	5	6	8
2½	3	1½	2,400	2,000	25,000	100,000	6	8	10

Note: For other drops in temperature and other rates of heat transmission, make all necessary corrections.

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frictional resistance per running foot in 0.001 in. of water column.

The following examples will illustrate the use of the data.

Example 1—The drop in temperature through the radiators is given as 20 F. Length of run including all equivalents is 210 ft. Total radiation (at 240 Btu per sq ft) is 2000 sq ft. Find the velocity of flow of water and friction in a 2 in. pipe.

Total Btu = $2000 \times 240 = 480$ MBtu

At intersection of 480 MBtu line and 2 in. pipe size line, read velocity is 5.1 fps and frictional resistance is 0.475 in. per ft or $0.475 \times 210 = 99.8$ in. for the circuit.

Example 2—The drop in temperature through the radiators is 25 F. Length of run including all equivalents is 315 ft. Total heat loss is 60 MBtu. Friction to be used up is 42 in. Find the pipe size required and the velocity of the flow of water.

Frictional resistance per ft is $42 \div 315 = 0.133$ in.

Heat loss at 20 F $= 60 \times (20 \div 25) = 48$.

At intersection of 0.133 frictional resistance line and 48 MBtu line, read pipe size is between 1 and 1¼ in. and velocity is 1.75 fps.

(*Note*—For the purpose of rapidly solving problems like the above, the author has prepared a copyrighted pipe size computer which operates as a slide rule and gives all relations involving the following six variables within the ranges cited:

1. Temperature drop—Between 10 and 60 F.
2. Heat transmitted—Between 0.5 MBtu and 20,000 MBtu on one slide, and between 2 sq ft and 100,000 sq ft at 240 Btu transmission rate on the other slide.
3. Equivalent length of circuit—Between 1 ft and 10,000 ft.
4. Size of pipes—Between ½ and 12 in.
5. Velocity of water—Between 0.10 and 60 fps.
6. Frictional resistance—Between 0.1 and 1000 in. water column.

Due to the logarithmic basis of the calculator, complete pictures of the problems present themselves to the mind and the percentage of error is equal within its entire range. It has reduced the time for calculating pipe sizes by more than 75 per cent.)

Table 2 gives the recommended pipe sizes for expansion, overflow and vent lines, the capacities of pumps and expansion tanks under ordinary conditions, and also the suggested sizes of mains and radiator connections to be used only for "trial" purposes.

Step by Step Example

Example 3 illustrates the successive steps required in calculating the pipe sizes for a forced hot water heating system. The lengths for circuits in each case represent the total equivalent lengths included in both the flow and return lines plus the equivalent for all fittings, etc. In some instances it may be expeditious to calculate the flow and return lines separately. Under such conditions allow one-half of the radiator and connections on the flow, and the other half on the return branch; that is, consider the middle of each radiator as a neutral point.

Example 3 (See Fig. 3)—Estimate the radiation the same as for steam systems. Assume a drop of 20 F through the radiators at 240 Btu per sq ft per hr. Lay out the piping system. Estimate the total radiation T (including all exposed pipe) and estimate the equivalent length of each division of the system as noted by adding the equivalent for all fittings, etc., to the actual length of the pipe and mark on the diagram. For instance, estimate the circuit *A-Radiator 1-B* for ¾ in. pipe as follows:

1 Radiator (Table 1)	6.0
1 Radiator valve (Table 1)	4.0
4 90 deg elbows (Table 1)	8.0
2 45 deg elbows (Table 1)	3.0
2 Tees (Table 1 and Fig. 1)	7.0
1 Equalizing non-reflux elbow	14.0 (To infinity)
Total	42.0 × ¾ in. = 31.5 ft
Actual length of pipe	13.5
Total equivalent length of pipe	45.0 ft

The circulator or pump should have a capacity of 12 gpm, with a suitable head—say 6 ft or 72 in. Select the pipe sizes so that the total resistance from the discharge of the pump through any radiator and back to the suction pump is equivalent to the total head produced by the pump. Hence, the resistance of all circuits terminating in two associated points as C and D, must be equal. That is, resistance R of *C-A-Radiator 1-B-D* must equal R of circuit *C-E-Radiator 3-F-D* and must equal R of circuit *C-E-Radiator 2-F-D*. Also R of circuit *E-Radiator 2-F* must equal R of circuit *E-Radiator 3-F*, etc. Unless these conditions are fulfilled radiators with too low a resistance in the circuit will rob the system. To compensate for the diminished circulation through the sluggish radiators, higher water temperatures are required, causing waste of fuel. Starting with the circuit farthest from the boiler, figure pipe sizes toward the boiler, as follows:

Step 1: Circuit *A-Radiator 1-B*. Assume ¾ in. pipe. By following the process of Example 1, find resistance R and velocity V and mark on plans.

Step 2: Circuit *AC* plus *BD* (sum of both pipes). Assume ¾ in. and 1 in. pipe. Find R and V for each and mark on plans. Then find total resistance S, (sum of Step 1 plus Step 2) for each and mark on plans. Select and check 1 in.

Step 3: Circuit *E-Radiator 2-F*. Assume ¾ in. pipe. Find R and V. Mark on plans.

Step 4: Circuit *C-E* plus *D-F*. Assume ¾ in. and 1 in. pipe. Find R, S and V for each. S of Step 4 must equal S of Step 2. Select and check 1 in.

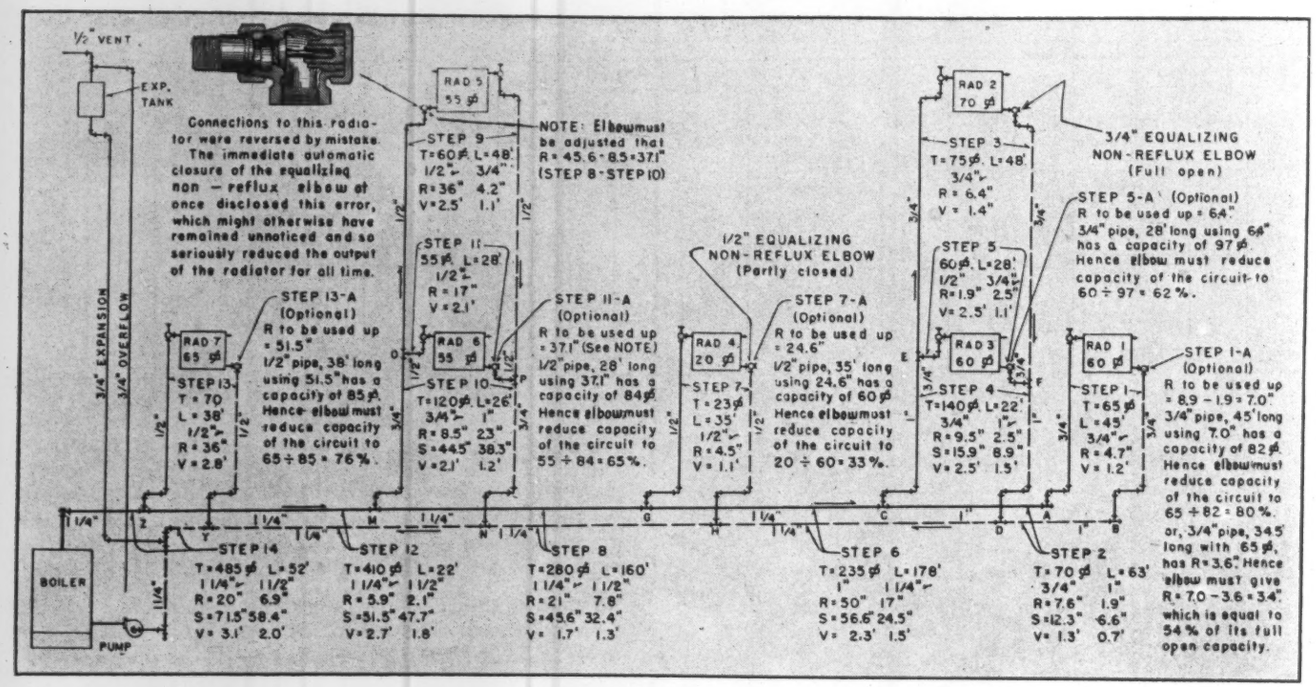
½" VENT
EXP. TANK
Connections to this radiator were reversed by mistake. The immediate automatic closure of the equalizing non-reflux elbow at once disclosed this error, which might otherwise have remained unnoticed and so seriously reduced the output of the radiator for all time.
3/4" EXPANSION
3/4" OVERFLOW
BOILER
PUMP
RAD 5 55 sf
STEP 9 T=60 sf L=48' 1/2" 3/4" R=36" 4.2" V=2.5' 1.1'
NOTE: Elbow must be adjusted that R=45.6-8.5=37.1" (STEP 8-STEP 10)
STEP 11 55 sf L=28' 1/2" R=17" V=2.1'
RAD 6 55 sf
STEP 10 T=120 sf L=26' 3/4" 1" R=8.5" 23" S=44.5" 38.3" V=2.1' 1.2'
STEP 11-A (Optional) R to be used up =37.1" (See NOTE) 1/2" pipe, 28' long using 37.1" has a capacity of 84 sf. Hence elbow must reduce capacity of the circuit to 55 ÷ 84 = 65%.
RAD 7 65 sf
STEP 13 T=70 L=38' 1/2" R=36" V=2.8'
STEP 13-A (Optional) R to be used up =51.5" 1/2" pipe, 38' long using 51.5" has a capacity of 85 sf. Hence elbow must reduce capacity of the circuit to 65 ÷ 85 = 76%.
1/2" EQUALIZING NON-REFLUX ELBOW (Partly closed)
RAD 4 20 sf
STEP 7 T=23 sf L=35' 1/2" R=4.5" V=1.1'
STEP 7-A (Optional) R to be used up =24.6" 1/2" pipe, 35' long using 24.6" has a capacity of 60 sf. Hence elbow must reduce capacity of the circuit to 20 ÷ 60 = 33%.
RAD 2 70 sf
STEP 3 T=75 sf L=48' 3/4" R=6.4" V=1.4'
3/4" EQUALIZING NON-REFLUX ELBOW (Full open)
STEP 5-A (Optional) R to be used up = 6.4" 3/4" pipe, 28' long using 6.4" has a capacity of 97 sf. Hence elbow must reduce capacity of the circuit to 60 ÷ 97 = 62%.
STEP 5 60 sf L=28' 1/2" 3/4" R=1.9" 2.5" V=2.5' 1.1'
RAD 3 60 sf
STEP 4 T=140 sf L=22' 3/4" 1" R=9.5" 2.5" S=15.9" 8.9" V=2.5' 1.5'
RAD 1 60 sf
STEP 1 T=65 sf L=45' 3/4" R=4.7" V=1.2'
STEP 1-A (Optional) R to be used up = 8.9 - 1.9 = 7.0" 3/4" pipe, 45' long using 7.0" has a capacity of 82 sf. Hence elbow must reduce capacity of the circuit to 65 ÷ 82 = 80%. or, 3/4" pipe, 34.5' long with 65 sf, has R=3.6". Hence elbow must give R = 7.0 - 3.6 = 3.4" which is equal to 54% of its full open capacity.
STEP 14 T=485 sf L=52' 1 1/4" 1 1/2" R=20" 6.9" S=71.5" 58.4" V=3.1' 2.0'
STEP 12 T=410 sf L=22' 1 1/4" 1 1/2" R=5.9" 2.1" S=51.5" 47.7" V=2.7' 1.8'
STEP 8 T=280 sf L=160' 1 1/4" 1 1/2" R=21" 7.8" S=45.6" 32.4" V=1.7' 1.3'
STEP 6 T=235 sf L=178' 1" 1 1/4" R=50" 17" S=56.6" 24.5" V=2.3' 1.5'
STEP 2 T=70 sf L=63' 3/4" 1" R=7.6" 1.9" S=12.3" 6.6" V=1.3' 0.7'

Fig. 3—Diagram illustrating Example 3 of text

T = sq ft of radiation. R = resistance. S = sum of resistances. V = Velocity. L = length of circuit.

Step 1A (Optional): As S of Step 2 is less than S of Step 4, additional resistance must be introduced in circuit *A-Radiator 1-B*. R to be used up is S of Step 4 minus S of Step 2, or 8.9 — 1.9 = 7.0 in. By following the process of Example 2, find ¾ in. pipe has capacity of 82 sq ft. Hence, the equalizing non-reflux elbow must be adjusted to reduce the capacity of circuit to 65 ÷ 82, or 80 per cent of its full capacity. (65 is the T of circuit *A-Radiator 1-B* of *Step 1*). The resistance of circuit A-Radiator 1-B without the equalizing elbow is (42 — 14) × ¾ = 21 ft, plus the actual length of pipe, 13.5 ft, = 34.5 ft total equivalent length. ¾ in. pipe, 34.5 ft long with 65 sq ft of load, has R = 3.6 in. Hence, the equalizing non-reflux elbow must produce R equal to the difference, or 7.0 — 3.6 = 3.4 in., or it must be set 54 per cent open. (From tests on elbows).

Step 5: Circuit *E-Radiator 3-F*. Assume the ½ and ¾ in. Find R and V. As R must equal R of Step 2, find ½ in. is too small. Use ¾ in. and adjust the equalizing non-reflux elbow of Radiator 3 to produce R, as per:

Step 5-A (Optional): As R of circuit *E-Radiator 3-F* must equal R of circuit *E-Radiator 2-F*, or 6.4 in., it will be necessary to adjust the equalizing non-reflux elbows to produce the required resistance.

In a similar manner follow through all ensuing steps. Try different pipe sizes and select such that the total resistance (S of Step 14) is equal to the friction head of the pump, or 72 in., and that the friction of any circuit is equal to or less than the total friction S of the preceding circuit or circuits. The deficits in friction are provided by the equalizing non-reflux elbows when the system is equalized with an electro-differential-thermometer, or by other accurate means.

It will be noted that factors of Fig. 1 need be used rarely. Hence, it is usually not necessary to note the velocities on plans.

The above calculations are based upon circulation due to pumpage only. They must further be corrected for the effects of gravity circulation. This is also best accomplished by the balancing process which is desirably carried on at a water temperature of 170 F when all discrepancies due to the effects of gravity circulation, errors in calculation, limitations imposed by the use of commercial pipe sizes, etc., are completely and effectively eliminated under operating conditions. It is not necessary to calculate the adjustment of the equalizing non-reflux elbows. Steps 1-*A*, 5-*A*, etc., are merely given to show the need of adjustment.

As seen from the above example, tables of pipe sizes are of no value except for trial purposes. *Radiator 1* of 60 sq ft capacity has a ¾ in. connection while *Radiator 7* of 65 sq ft capacity has only a ½ in. connection. I have found risers with less than 200 sq ft load requiring 1¼ in. pipe, while in the same system risers with 240 sq ft load required only ½ in. pipe, and the radiator branches on the latter risers needed throttling.

The above outlined method of design and estimating pipe sizes has proved very satisfactory and correct and led to extremely low initial and operating costs.

Smoke Abatement

Firing brings into the smoke abatement picture the human element and is the heart of the problem. The person who does the firing holds the key to the most important possible contribution to the abatement of smoke. Poor operating methods due to carelessness or lack of knowledge cause more smoke than all other reasons. It is here that most every one of us can do something, whether we do any actual firing or not. Let everyone consider it a part of his individual responsibility to do what he can to minimize the pollution of the atmosphere by familiarizing himself with proper firing methods.—Louis J. Henkel, Building Manager, Chamber of Commerce Bldg., Cincinnati, in a radio address.

Performance of Coils for Dehumidifying Air

By William Goodman*

New and simple formulas are developed by the author for computing the final dry and wet bulb temperatures of the air leaving a coil. Particularly noteworthy is the fact that the final wet bulb depression of the air is shown to depend upon the initial wet bulb depression of the air for both direct expansion and counterflow coils. This makes computation of the final dry bulb temperature the work of a moment

THE discussions of boundary dry bulb and surface temperature given in earlier parts of this series make it possible to point out the relationship between the condition curve presented here and the dehumidification process usually described in text books. In most texts, the air is first assumed to cool from its initial condition to the saturation curve without any dehumidification of the air taking place; in other words, from point "1" to point "2" of Fig. 16. After the air has been cooled to point "2," it is then supposed to cool along the saturation curve to the final condition represented by point "3." Such a dehumidifying cycle or condition curve represents a theoretical limiting case that cannot be obtained in actual practice—regardless of the equipment used to cool and dehumidify the air. As shown in Appendix 12, such a cooling cycle can take place only if either the surface film coefficient f_s, or the area ratio B, is infinite in value. If either f_s or B is infinite in value, no dehumidification of the air can take place until the dry bulb temperature of the air has been cooled to a point equal to its initial dew point temperature—that is, the air has been cooled to saturation at point "2." Further cooling of the air would result in condensation and cooling of the air along the saturation curve to the final condition represented by point "3." If the area of the coil is also infinite in extent, the air will be cooled to the temperature of the refrigerant. In this case, point "3" will move down until it coincides with point "4" representing the temperature of the refrigerant.

Another theoretical limiting case is obtained when either the refrigerant film coefficient f_R becomes infinite in value, or the value of B becomes zero. In this case, the surface temperature of the metal is constant throughout and equal to the constant refrigerant temperature. This is demonstrated in Appendix 13, where the fact is also demonstrated that if the surface temperature is constant and equal to the refrigerant temperature, the condition curve becomes a straight line drawn from point "1" to point "4" of Fig. 16.

The statements in the preceding paragraphs are also true in the case of counterflow coils if an infinite quantity of water or other refrigerant is supplied. In such a case the surface temperature will also be constant and equal to the initial refrigerant temperature, and the straight line representing the condition of the air will be drawn from point "1" of Fig. 16 to point "4" representing the initial temperature of the refrigerant.

The triangle formed by points "1," "2," and "4" of Fig. 16 encloses all the final points to which air can be cooled and dehumidified by any kind of an air conditioning apparatus regardless of whether it is a surface dehumidifier or a spray type cooler. With finite values of the coefficients f_s and f_R, the condition curve for the air flowing over a wetted surface must always lie inside the triangle "1-2-4," like the dotted curves "1-5-4" or "1-7-4" of Fig. 16. The greater the value of either f_s or B, or the smaller the value of f_R, the closer the condition curve will tend to move up toward the line "1-2." On the other hand, with increasing values of f_R, or with decreasing values of f_s and B, the condition curve will tend to move down toward the line "1-4."

In the foregoing discussion, the statement has been made that with an infinite surface area, the air can finally be cooled to saturation at a temperature equal to the initial refrigerant temperature; in other words, to point "4" of Fig. 16. This, however, is not always the case. Even when the surface area is infinite in extent, the

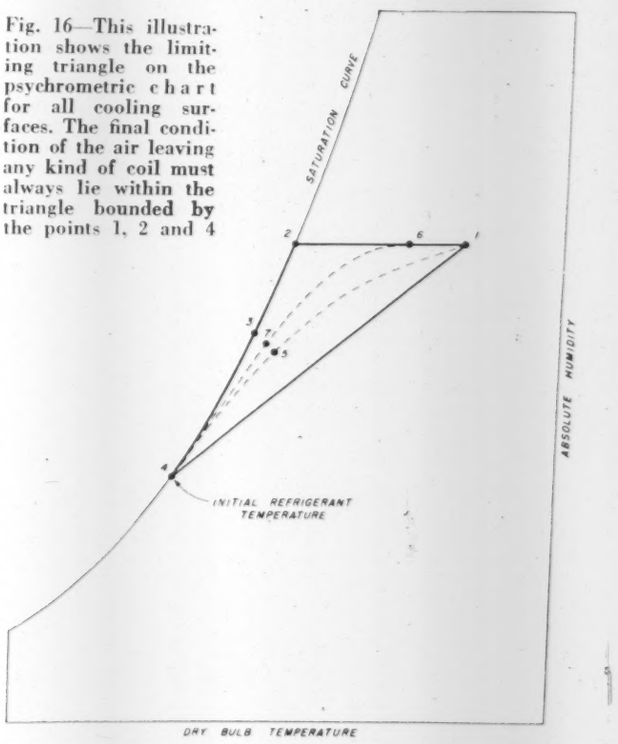

Fig. 16—This illustration shows the limiting triangle on the psychrometric chart for all cooling surfaces. The final condition of the air leaving any kind of coil must always lie within the triangle bounded by the points 1, 2 and 4

*The Trane Co. Member of Board of Consulting and Contributing Editors.

Part 4. Part 1 was published in November, 1938, pp. 697-701 and 707; Part 2 in December, 1938, pp. 777-781; and Part 3 in January, 1939, pp. 13-19.

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condition curve may still end on the saturation curve at a point above the initial refrigerant temperature. As shown in Appendix 14 for direct expansion coils and for counterflow coils for which the value $Ga/G'c'$ is equal to or less than one, the condition curve always ends at point "4." However, when $Ga/G'c'$ is greater than one, the derivation in Appendix 14 also shows that the lowest wet bulb temperature to which the air can be cooled is *higher* than the initial temperature of the refrigerant even if the surface area is infinite. In this case, the air leaving the infinite surface will be saturated, but the temperature will be higher than the initial temperature of the refrigerant.

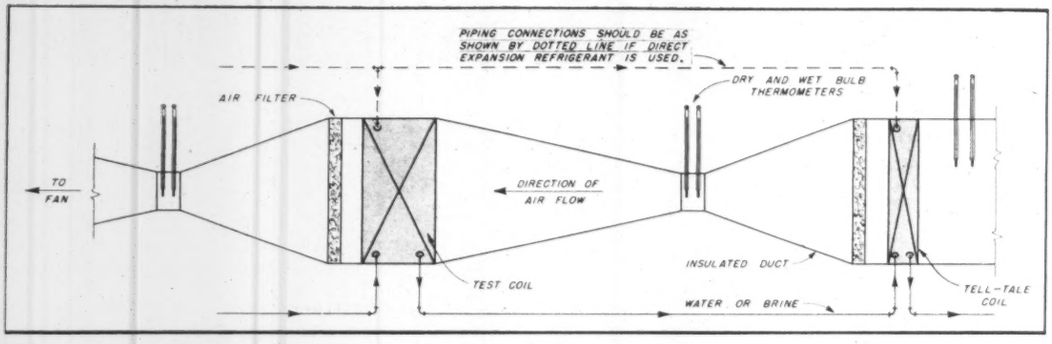
PIPING CONNECTIONS SHOULD BE AS SHOWN BY DOTTED LINE IF DIRECT EXPANSION REFRIGERANT IS USED.
AIR FILTER
DRY AND WET BULB THERMOMETERS
TO FAN
DIRECTION OF AIR FLOW
INSULATED DUCT
TEST COIL
TELL-TALE COIL
WATER OR BRINE

Fig. 17—Diagrammatic illustration of a desirable form of test set-up for determining coil performance. The dotted lines show the connections of the liquid refrigerant when direct expansion coils are being used

As shown in Appendix 14, when the surface area of a counterflow coil is infinite in extent and $Ga/G'c'$ is greater than one, the final temperature of the refrigerant will be equal to the initial wet bulb temperature of the air, or $t_{R2} = t'_1$. With the final temperature of the refrigerant known, the lowest final enthalpy of the air, and hence the lowest final wet bulb temperature to which the air can be cooled, may be computed by means of the following equation representing a heat balance between the air and refrigerant. This equation is valid only for this special case because t'_1 has been substituted for t_{R2}.

$$G(h_1 - h_2) = G'c'(t'_1 - t_{R1}) \quad \ldots\ldots\ldots\ldots\ldots\ldots [31]$$

The final wet bulb temperature to which the air can be cooled in a coil of infinite area when $Ga/G'c'$ is greater than one can be found by solving for h_2 by means of this equation. Also, as shown in Appendix 14, under these conditions the final dry bulb temperature of the air will be equal to the final wet bulb temperature. Hence, the air will leave the coil saturated but at some temperature higher than the initial refrigerant temperature.

The limiting conditions described in this section should be thoroughly understood as they are often of value in quickly visualizing the probable results that may be expected in a given situation.

Determining Film Coefficients by Test

The values of the film coefficients can be determined by tests on coils without any difficult measurements of surface temperature. For this purpose, tests are first run on completely wetted coils—there should be no dry surface on the coil during the test. Dry surface can be detected easily as explained later. After running a series of tests on wetted surface, the values of U_W can be found by means of Equation 1.

After the values of U_W have been determined, either one of two methods can be used to determine the individual film coefficients. The first method requires that a second series of tests be run on the coil with the surface completely dry. From such tests the values of U_D can be computed by means of Equation 17. Knowing the values of U_D and U_W for the different air and refrigerant velocities for which the coil was tested, the

Symbols

a = a numerical coefficient. See Table 1.
A_D = external area of dry surface, sq ft.
A_T = total external area of coil surface, sq ft.
A_W = external area of wetted surface, sq ft.
B = ratio of external to internal surface area of coil.
c = humid specific heat of air (average $c = 0.243$).
c' = specific heat of refrigerant.
d_L = large enthalpy (total heat) difference, Btu.
d_M = mean enthalpy (total heat) difference, Btu.
d_S = small enthalpy (total heat) difference, Btu.
f_g = coefficient of heat transfer through air film, Btu per hr per sq ft per degree of temperature difference.
f_R = coefficient of heat transfer through refrigerant film, Btu per hr per sq ft per degree of temperature difference.
G = weight of air, lb per hr.
G' = weight of refrigerant, lb per hr.
h = enthalpy (total heat) of humid air, Btu per lb of dry air.
h_R = enthalpy (total heat) of saturated air at temperature equal to the refrigerant temperature, Btu per lb of dry air.
h_S = enthalpy (total heat) of saturated air at a temperature equal to the surface temperature, Btu per lb of dry air.
H_S = sensible heat lost by the air flowing past the wetted surface, Btu per hr.
H_W = total heat lost by the air flowing past the wetted surface, Btu per hr.
M = a numerical factor. See Equations 7, 11 and 24.
t = dry bulb temperature, deg Fahr.
t' = wet bulb temperature, deg Fahr.
t_R = refrigerant temperature, deg Fahr.
t_S = surface temperature of coil, deg Fahr.
U_D = over-all coefficient of heat transfer through dry surface of coil, Btu per hr per sq ft per degree of temperature difference.
U_W = over-all coefficient of heat transfer through wetted surface of coil, Btu per hr per sq ft per Btu of enthalpy difference.

The subscript "1" refers to the initial condition of the air or refrigerant entering the coil. The subscript "2" refers to the final condition of the air or refrigerant leaving the coil.

values of f_R can be determined by means of the following equation which is obtained by eliminating f_g between Equations 2 and 3.

$$f_R = \frac{B(a-c)}{\frac{1}{U_W} - \frac{c}{U_D}} \quad \text{.....[32]}$$

After the values of f_R have been evaluated for the various tests they can be used in Equation 2 to solve for f_g. If the coefficients are obtained in this manner, the results can be applied accurately to coils of various areas which differ markedly from the area of the coil tested. Satisfactory results have been obtained in this manner for the tests described in Appendix 15, which were used to verify the validity of the methods presented here.

The second method used to evaluate the film coefficients does not require any dry surface tests. Equation 8 is used to determine the values of f_g from the results of the wet surface tests alone. With the values of both f_g and U_W known, Equation 3 can then be used to find the values of f_R.

As shown in Appendix 15, the results obtained by the two methods are in fair agreement, although tests analyzed by the second method do not give results that are as accurate as those obtained by running dry surface tests in addition to the wet surface tests. Perhaps the reason for this is to be found in the fact that dry surface tests can be run more accurately than wet surface tests. Because of the relative accuracy with which dry surface tests can be run, their use tends to result in more accurate and consistent values of the film coefficients. Improved experimental technique in the running of wet surface tests may possibly eliminate the need for dry surface tests in the future.

In running the tests on wetted surface, it is essential that there should be no dry surface on the coil, because the derivation of Equation 1 is based on the assumption that the entire surface of the coil will be wetted by the moisture condensed from the air. In order to be sure that there is no dry surface in the coil during the tests of the wetted coil, a tell-tale coil should be used as shown in Fig. 17. In direct expansion tests the refrigerant supplied to both coils should be at the same temperature. In counterflow coil tests, the water leaving the test coil should be carried through the tell-tale coil before it is discharged to the sewer or returned to the water cooler. By taking wet and dry bulb temperature readings before and after the tell-tale coil, a drop in the dew point temperature of the air while it flows through the tell-tale coil can be detected. If the dew point temperature is lowered while flowing through the tell-tale coil, then there can be no dry surface on the test coil. On the other hand, if there is no change in the dew point temperature of the air while flowing through the tell-tale coil, then the tell-tale coil is dry and there is every possibility that a portion of the test coil will also be dry.

The glass wool filters shown in Fig. 17 are used to remove entrained moisture which might otherwise be deposited on the thermometers. These filters must be dried by a hot blast of air after each run during the course of the test; otherwise, when they become thoroughly wet, the air flowing through them will entrain more moisture.

Tests made without the use of tell-tale coils are always open to the suspicion that a portion of the supposedly wetted coil being tested may be dry. For this reason, a tell-tale coil is always desirable in test work.

Frost

If the refrigerant temperature is lower than 32 F, frost may form on the coil. If this occurs, the heat removed in freezing the condensed moisture must be accounted for. Frosted coils will not be discussed here except to show how to determine whether or not frost will form on a coil.

To determine whether or not frost will occur, Equation 12 may be used. Frosting cannot take place unless the surface temperature is 32 deg or lower. Therefore, inserting 32 deg for t_s, and 11.74 (the enthalpy of saturated air at 32 deg) for h_s, the following variation of Equation 12 is obtained:

$$h = 11.74 + \frac{cf_R}{Bf_g}(32 - t_R) \quad \text{.....[33]}$$

This equation can be used to solve for h, the enthalpy of air at the instant it is flowing over the point on the coil where frost is beginning to form. Knowing the value of h, the wet bulb temperature of the air at this point can be determined from Table 4. If the final wet bulb temperature of the air leaving the coil is higher than the wet bulb temperature determined by means of Equation 33, there will be no frost on the coil. However, if the final wet bulb temperature is lower, frost will form on that portion of the coil over which the wet bulb temperature of the air is lower than the temperature determined by means of Equation 33.

Appendix 1

Derivation of $dH_W = \frac{f_g}{c}(h - h_s)\,dA_W$

The sensible heat lost by the air flowing past an infinitesimally small portion of the cold wetted surface dA_W is

$$dH_s = f_g(t - t_s)\,dA_W \quad \text{.....[1]}$$

The weight of moisture condensed from the air-vapor mixture while flowing past this infinitesimally small element of cold wetted surface is

$$dW = k(w - w_s)\,dA_W \quad \text{.....[2]}$$

where k = coefficient of vapor transfer through the air film;
w = absolute humidity of air flowing past the surface;
w_s = absolute humidity of saturated surface film;
dW = weight of moisture condensed from air on area dA_W

According to Lewis,[4] the following relationship is very nearly true for mixtures of air and water vapor.

$$k = \frac{f_g}{c} \quad \text{.....[3]}$$

Substituting [3] into [2],

$$dW = \frac{f_g}{c}(w - w_s)\,dA_W \quad \text{.....[4]}$$

In the reference of Footnote 3, it is shown that

$$h = ct + 1061w \quad \text{.....[5]}$$

Similarly,

$$h_s = ct_s + 1061w_s \quad \text{.....[6]}$$

Subtracting [6] from [5] and rearranging terms,

$$w - w_s = \frac{(h - h_s) - c(t - t_s)}{1061} \quad \text{.....[7]}$$

(At low dew point temperatures, c is very nearly constant.)
Substitute [7] into [4].

[4] Lewis, W. K., The Evaporation of a Liquid into a Gas, ASME *Transactions*, Vol. 44, 1922, p. 325.

$$1061dW = \frac{f_g}{c}(h - h_s)\,dA_w - f_g(t - t_s)\,dA_w \quad ..[8]$$

Add [1] to [8].

$$dH_s + 1061dW = \frac{f_g}{c}(h - h_s) \quad .....[9]$$

Now,

$$dH_s = -Gcdt \quad .....[10]$$

and

$$1061dW = -1061Gdw \quad .....[11]$$

Adding [10] and [11],

$$dH_s + 1061dW = -G(cdt + 1061dw) \quad .....[12]$$

But differentiating [5],

$$dh = cdt + 1061dw \quad .....[13]$$

Substituting [13] into [12],

$$dH_s + 1061dW = -Gdh = dH_w \quad .....[14]$$

Substituting [14] into [9],

$$dH_w = \frac{f_g}{c}(h - h_s)\,dA_w \quad .....[15]$$

This equation was first derived by Merkel[5], although the derivation given above differs from his.

Appendix 2

Derivation of Equation 1 for Direct Expansion Coils $H_w = A_w U_w d_M$

According to Equation 15 of Appendix 1, the total heat lost by the air-vapor mixture and transferred through the outside air film is

$$dH_w = \frac{f_g}{c}(h - h_s)\,dA_w \quad .....[1]$$

Neglecting the negligibly small amount of heat carried away by the condensate draining from the surface, the total heat lost by the air is eventually transferred through the refrigerant film inside the tube, or

$$dH_w = \frac{f_R}{B}(t_s - t_R)\,dA_w \quad .....[2]$$

Now since the air in the outside surface film is saturated, the value of h_s in [1] depends upon the value of t_s. Therefore, if h_s can be expressed in terms of t_s, these quantities can be eliminated by a simultaneous solution of Equations 1 and 2, and a new equation obtained. However, as there is no rational equation relating h_s to t_s, an empirical relationship must be used. As shown in Appendices 3 and 4, an empirical relation of the following form can be used for this purpose.

$$\frac{h_s - h_R}{t_s - t_R} = a \quad .....[3]$$

Substituting [3] into [2],

$$dH_w = \frac{f_R}{Ba}(h_s - h_R)\,dA_w \quad .....[4]$$

Eliminating h_s between [1] and [4], and reassembling terms,

$$\left[\frac{c}{f_g} + B\frac{a}{f_R}\right]\frac{dH_w}{dA_w} = h - h_R \quad .....[5]$$

Let

$$\frac{1}{U_w} = \frac{c}{f_g} + B\frac{a}{f_R} \quad .....[6]$$

This is Equation 3 of the text.

Substituting [6] into [5], and rearranging,

$$\frac{dH_w}{h - h_R} = U_w dA_w \quad .....[7]$$

But the total heat lost by the air as its enthalpy decreases is

$$dH_w = -Gdh \quad .....[8]$$

Therefore,

$$\frac{dh}{h - h_R} = -\frac{U_w}{G}dA_w \quad .....[9]$$

Integrating [9],

$$\mathrm{Log_e}\frac{h_1 - h_R}{h_2 - h_R} = \frac{A_w U_w}{G} \quad .....[10]$$

$$\mathrm{Log_e}\frac{d_L}{d_s} = \frac{A_w U_w}{G} \quad .....[11]$$

(Equation 7 of the text is obtained by letting $M = A_w U_w / G$).

[5]Merkel, *Zeit. ges. Kalte Industrie*, Vol. 34, p. 117, July, 1927.

Now

$$H_w = G(h_1 - h_2) \quad .....[12]$$

$$= G[(h_1 - h_R) - (h_2 - h_R)] \quad .....[13]$$

$$= G(d_L - d_s) \quad .....[14]$$

Therefore,

$$\frac{1}{G} = \frac{d_L - d_s}{H_w} \quad .....[15]$$

Substitute [15] into [11].

$$\mathrm{Log_e}\frac{d_L}{d_s} = \frac{A_w U_w}{H_w}(d_L - d_s) \quad .....[16]$$

$$H_w = A_w U_w \left[\frac{d_L - d_s}{\mathrm{Log_e}\dfrac{d_L}{d_s}}\right] \quad .....[17]$$

Let

$$d_M = \frac{d_L - d_s}{\mathrm{Log_e}\dfrac{d_L}{d_s}} \quad .....[18]$$

Therefore, $H_w = A_w U_w d_M$ .....[19]

This is Equation 1 of the text.

The values in Tables 2 and 3 were computed by means of the following equations derived from Equations 11, 18 and 20 of this appendix.

$$\mathrm{Log_e}\frac{d_L}{d_s} = M \quad .....[20]$$

$$\frac{d_M}{d_L} = \frac{1}{M}\left[1 - \frac{d_s}{d_L}\right] \quad .....[21]$$

$$\frac{d_M}{d_s} = \frac{1}{M}\left[\frac{d_L}{d_s} - 1\right] \quad .....[22]$$

[To be continued]

Properties of Air-Vapor Mixtures Interpolated to Tenths of a Degree

By William Goodman*

THE tables on the next two pages are continued from the one published on p. 36 of the January, 1939, HPAC; with the January table appeared a brief explanation of them. Publication of these tables will be continued next month.

The values in Columns 3 and 4 are extremely useful for quickly finding the *actual* enthalpy (total heat) of an air-vapor mixture if its dry bulb and dew point temperatures are known. A complete discussion was given in the January, 1938, HPAC[1] of the method of using the actual enthalpy of the air for accurate computations as against the approximate methods commonly used. Although the error is generally not large, there are times when accurate computations using the actual enthalpy should be used. In such cases the equation below, which was developed in the earlier article, offers the quickest means of finding the actual enthalpy if the dry bulb and dew point temperatures are known.

$$h = s''\,t + 1061w$$

where h = actual enthalpy of the mixture, Btu per lb of dry air;
t = dry bulb temperature of the air.

Values of s'', the humid specific heat of air corresponding to any given *dew point* temperature, are tabulated in Column 3. Values of $1061w$ corresponding to the *dew point* temperatures are tabulated in Column 4.

*The Trane Co. Member of Board of Consulting and Contributing Editors.

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[1]"New Tables of the Psychrometric Properties of Air-Vapor Mixtures," Heating, Piping and Air Conditioning, January, 1938, pp. 1-7.

Absolute Humidity and Enthalpy of Mixtures of Air and Saturated Water Vapor

Interpolated to Tenths of a Degree.
Barometric Pressure 14.696 Lb per Sq In.
All Tabulated Values are Quantities per Pound of Dry Air in the Mixture.

Temp. Deg Fahr t	Absolute Humidity Pounds w	Humid Specific Heat s'	$1061w$	Enthalpy of Air-Vapor Mixture Btu h	Temp. Deg Fahr t
1	2	3	4	5	6
— 3.0	0.0008111	0.2404	0.8606	0.1394	— 3.0
.9	.0008151		.8648	.1677	9
.8	.0008191		.8691	.1960	8
.7	.0008231		.8733	.2242	7
.6	.0008271		.8775	.2525	6
— 2.5	0.0008311	0.2404	0.8818	0.2808	— 2.5
.4	.0008350		.8860	.3091	4
.3	.0008390		.8902	.3374	3
.2	.0008430		.8944	.3656	2
.1	.0008470		.8987	.3939	1
— 2.0	0.0008510	0.2404	0.9029	0.4222	— 2.0
.9	.0008552		.9073	.4507	9
.8	.0008593		.9117	.4791	8
.7	.0008635		.9162	.5076	7
.6	.0008676		.9206	.5360	6
— 1.5	0.0008718	0.2404	0.9250	0.5645	— 1.5
.4	.0008760		.9294	.5929	4
.3	.0008801		.9338	.6214	3
.2	.0008843		.9383	.6498	2
.1	.0008884		.9427	.6783	1
— 1.0	0.0008926	0.2404	0.9471	0.7067	— 1.0
.9	.0008969		.9516	.7352	9
.8	.0009011		.9561	.7638	8
.7	.0009054		.9606	.7923	7
.6	.0009096		.9651	.8209	6
— 0.5	0.0009139	0.2404	0.9696	0.8494	— 0.5
.4	.0009181		.9741	.8779	4
.3	.0009224		.9786	.9065	3
.2	.0009266		.9831	.9350	2
.1	.0009309		.9876	.9636	1
0.0	0.0009351	0.2404	0.9921	0.9921	0.0
.1	.0009396		0.9969	1.021	1
.2	.0009440		1.002	1.050	2
.3	.0009485		1.007	1.079	3
.4	.0009529		1.011	1.107	4
0.5	0.0009574	0.2404	1.016	1.136	0.5
.6	.0009619		1.021	1.165	6
.7	.0009663		1.026	1.194	7
.8	.0009708		1.030	1.222	8
.9	.0009752		1.035	1.251	9
1.0	0.0009797	0.2404	1.040	1.280	1.0
.1	.0009843		1.045	1.309	1
.2	.0009890		1.050	1.338	2
.3	.0009936		1.055	1.367	3
.4	.0009982		1.060	1.396	4
1.5	0.001003	0.2405	1.065	1.425	1.5
.6	.001008		1.069	1.454	6
.7	.001012		1.074	1.483	7
.8	.001017		1.079	1.512	8
.9	.001021		1.084	1.541	9
2.0	0.001026	0.2405	1.089	1.570	2.0
.1	.001031		1.094	1.599	1
.2	.001036		1.099	1.628	2
.3	.001041		1.105	1.658	3
.4	.001046		1.110	1.687	4
2.5	0.001051	0.2405	1.115	1.716	2.5
.6	.001055		1.120	1.745	6
.7	.001060		1.125	1.774	7
.8	.001065		1.131	1.804	8
.9	.001070		1.136	1.833	9
3.0	0.001075	0.2405	1.141	1.862	3.0
.1	.001080		1.147	1.892	1
.2	.001085		1.152	1.921	2
.3	.001091		1.158	1.951	3
.4	.001096		1.163	1.980	4
3.5	0.001101	0.2405	1.169	2.010	3.5
.6	.001106		1.174	2.039	6
.7	.001111		1.180	2.069	7
.8	.001117		1.185	2.098	8
.9	.001122		1.191	2.128	9
4.0	0.001127	0.2405	1.196	2.157	4.0
.1	.001132		1.202	2.187	1
.2	.001137		1.207	2.216	2
.3	.001143		1.213	2.246	3
.4	.001148		1.218	2.276	4
4.5	0.001153	0.2405	1.224	2.306	4.5
.6	.001158		1.229	2.335	6
.7	.001163		1.235	2.365	7
.8	.001169		1.240	2.395	8
.9	.001174		1.246	2.424	9
5.0	0.001179	0.2405	1.251	2.454	5.0
.1	.001185		1.257	2.484	1
.2	.001190		1.263	2.514	2
.3	.001196		1.268	2.544	3
.4	.001201		1.274	2.574	4
5.5	0.001207	0.2405	1.280	2.604	5.5
.6	.001212		1.286	2.633	6
.7	.001218		1.292	2.663	7
.8	.001223		1.297	2.693	8
.9	.001229		1.303	2.723	9
6.0	0.001234	0.2406	1.309	2.753	6.0
.1	.001240		1.315	2.783	1
.2	.001246		1.321	2.813	2
.3	.001251		1.328	2.843	3
.4	.001257		1.334	2.873	4
6.5	0.001263	0.2406	1.340	2.904	6.5
.6	.001269		1.346	2.934	6
.7	.001275		1.352	2.964	7
.8	.001280		1.359	2.994	8
.9	.001286		1.365	3.024	9
7.0	0.001292	0.2406	1.371	3.054	7.0
.1	.001298		1.377	3.085	1
.2	.001304		1.383	3.115	2
.3	.001310		1.390	3.146	3
.4	.001316		1.396	3.176	4
7.5	0.001322	0.2406	1.402	3.207	7.5
.6	.001327		1.408	3.237	6
.7	.001333		1.414	3.268	7
.8	.001339		1.421	3.298	8
.9	.001345		1.427	3.329	9
8.0	0.001351	0.2406	1.433	3.359	8.0
.1	.001357		1.440	3.390	1
.2	.001364		1.446	3.420	2
.3	.001370		1.453	3.451	3
.4	.001376		1.460	3.482	4
8.5	0.001383	0.2406	1.467	3.513	8.5
.6	.001389		1.473	3.543	6
.7	.001395		1.480	3.574	7
.8	.001401		1.487	3.605	8
.9	.001408		1.493	3.635	9
9.0	0.001414	0.2406	1.500	3.666	9.0
.1	.001421		1.507	3.697	1
.2	.001427		1.514	3.728	2
.3	.001434		1.521	3.759	3
.4	.001440		1.528	3.790	4
9.5	0.001447	0.2407	1.535	3.821	9.5
.6	.001453		1.541	3.852	6
.7	.001460		1.548	3.883	7
.8	.001466		1.555	3.914	8
.9	.001473		1.562	3.945	9
10.0	0.001479	0.2407	1.569	3.976	10.0
.1	.001486		1.576	4.007	1
.2	.001493		1.584	4.039	2
.3	.001499		1.591	4.070	3
.4	.001506		1.598	4.102	4
10.5	0.001513	0.2407	1.606	4.133	10.5
.6	.001520		1.613	4.164	6
.7	.001527		1.620	4.196	7
.8	.001533		1.627	4.227	8
.9	.001540		1.635	4.259	9
11.0	0.001547	0.2407	1.642	4.290	11.0
.1	.001554		1.649	4.322	1
.2	.001561		1.657	4.353	2
.3	.001568		1.664	4.385	3
.4	.001575		1.672	4.416	4
11.5	0.001583	0.2407	1.679	4.448	11.5
.6	.001590		1.686	4.479	6
.7	.001597		1.694	4.511	7
.8	.001604		1.701	4.542	8
.9	.001611		1.709	4.574	9
12.0	0.001618	0.2407	1.716	4.605	12.0
.1	.001625		1.724	4.637	1
.2	.001632		1.731	4.668	2
.3	.001639		1.739	4.700	3
.4	.001646		1.746	4.732	4
12.5	0.001654	0.2407	1.754	4.764	12.5
.6	.001661		1.762	4.795	6
.7	.001668		1.769	4.827	7
.8	.001675		1.777	4.859	8
.9	.001682		1.784	4.890	9
13.0	0.001689	0.2408	1.792	4.922	13.0
.1	.001697		1.800	4.954	1
.2	.001705		1.809	4.987	2
.3	.001712		1.817	5.019	3
.4	.001720		1.825	5.052	4
13.5	0.001728	0.2408	1.834	5.084	13.5
.6	.001736		1.842	5.116	6
.7	.001744		1.850	5.149	7
.8	.001751		1.858	5.181	8
.9	.001759		1.867	5.214	9

[See preceding page]

Absolute Humidity and Enthalpy of Mixtures of Air and Saturated Water Vapor

Interpolated to Tenths of a Degree.
Barometric Pressure 14.696 Lb per Sq In.
All Tabulated Values are Quantities per Pound of Dry Air in the Mixture.

Temp. Deg Fahr t	Absolute Humidity Pounds w	Humid Specific Heat s'	1061w	Enthalpy of Air-Vapor Mixture Btu h	Temp. Deg Fahr t
1	2	3	4	5	6
14.0	0.001767	0.2408	1.875	5.246	14.0
.1	.001775		1.883	5.279	.1
.2	.001783		1.892	5.311	.2
.3	.001791		1.900	5.344	.3
.4	.001799		1.909	5.376	.4
14.5	0.001807	0.2408	1.917	5.409	14.5
.6	.001814		1.925	5.441	.6
.7	.001822		1.934	5.474	.7
.8	.001830		1.942	5.506	.8
.9	.001838		1.951	5.539	.9
15.0	0.001846	0.2408	1.959	5.571	15.0
.1	.001854		1.968	5.604	.1
.2	.001862		1.976	5.637	.2
.3	.001871		1.985	5.670	.3
.4	.001879		1.994	5.703	.4
15.5	0.001887	0.2409	2.003	5.736	15.5
.6	.001895		2.011	5.768	.6
.7	.001903		2.020	5.801	.7
.8	.001912		2.029	5.834	.8
.9	.001920		2.037	5.867	.9
16.0	0.001928	0.2409	2.046	5.900	16.0
.1	.001937		2.055	5.933	.1
.2	.001945		2.064	5.966	.2
.3	.001954		2.073	5.999	.3
.4	.001962		2.082	6.032	.4
16.5	0.001971	0.2409	2.091	6.066	16.5
.6	.001979		2.100	6.099	.6
.7	.001988		2.109	6.132	.7
.8	.001996		2.118	6.165	.8
.9	.002005		2.127	6.198	.9
17.0	0.002013	0.2409	2.136	6.231	17.0
.1	.002022		2.145	6.265	.1
.2	.002031		2.155	6.298	.2
.3	.002040		2.164	6.332	.3
.4	.002049		2.174	6.365	.4
17.5	0.002058	0.2409	2.183	6.399	17.5
.6	.002066		2.192	6.433	.6
.7	.002075		2.202	6.466	.7
.8	.002084		2.211	6.500	.8
.9	.002093		2.221	6.533	.9
18.0	0.002102	0.2410	2.230	6.567	18.0
.1	.002111		2.240	6.601	.1
.2	.002121		2.250	6.635	.2
.3	.002130		2.260	6.669	.3
.4	.002139		2.270	6.703	.4
18.5	0.002149	0.2410	2.280	6.738	18.5
.6	.002158		2.289	6.772	.6
.7	.002167		2.299	6.806	.7
.8	.002176		2.309	6.840	.8
.9	.002186		2.319	6.874	.9
19.0	0.002195	0.2410	2.329	6.908	19.0
.1	.002205		2.339	6.942	.1
.2	.002214		2.349	6.976	.2
.3	.002224		2.359	7.011	.3
.4	.002233		2.369	7.045	.4
19.5	0.002243	0.2410	2.380	7.079	19.5
.6	.002252		2.390	7.113	.6
.7	.002262		2.400	7.147	.7
.8	.002271		2.410	7.182	.8
.9	.002281		2.420	7.216	.9
20.0	0.002290	0.2410	2.430	7.250	20.0
.1	.002300		2.441	7.285	.1
.2	.002310		2.451	7.320	.2
.3	.002320		2.462	7.355	.3
.4	.002330	0.2411	2.473	7.390	.4
20.5	0.002341	0.2411	2.484	7.425	20.5
.6	.002351		2.494	7.460	.6
.7	.002361		2.505	7.495	.7
.8	.002371		2.516	7.530	.8
.9	.002381		2.526	7.565	.9
21.0	0.002391	0.2411	2.537	7.600	21.0
.1	.002401		2.548	7.635	.1
.2	.002412		2.559	7.670	.2
.3	.002422		2.570	7.705	.3
.4	.002432		2.581	7.740	.4
21.5	0.002443	0.2411	2.592	7.776	21.5
.6	.002453		2.602	7.811	.6
.7	.002463		2.613	7.846	.7
.8	.002473		2.624	7.881	.8
.9	.002484		2.635	7.916	.9
22.0	0.002494	0.2411	2.646	7.951	22.0
.1	.002505		2.658	7.987	.1
.2	.002516		2.669	8.022	.2
.3	.002526		2.681	8.058	.3
.4	.002537		2.692	8.094	.4
22.5	0.002548	0.2411	2.704	8.130	22.5
.6	.002559	0.2412	2.715	8.165	.6
.7	.002570		2.727	8.201	.7
.8	.002580		2.738	8.237	.8
.9	.002591		2.750	8.272	.9
23.0	0.002602	0.2412	2.761	8.308	23.0
.1	.002613		2.773	8.344	.1
.2	.002624		2.785	8.380	.2
.3	.002636		2.797	8.416	.3
.4	.002647		2.809	8.452	.4
23.5	0.002658	0.2412	2.821	8.489	23.5
.6	.002669		2.832	8.525	.6
.7	.002680		2.844	8.561	.7
.8	.002692		2.856	8.597	.8
.9	.002703		2.868	8.633	.9
24.0	0.002714	0.2412	2.880	8.669	24.0
.1	.002725		2.892	8.705	.1
.2	.002737		2.904	8.742	.2
.3	.002748		2.916	8.778	.3
.4	.002760		2.928	8.815	.4
24.5	0.002771	0.2412	2.941	8.851	24.5
.6	.002782	0.2413	2.953	8.887	.6
.7	.002794		2.965	8.924	.7
.8	.002805		2.977	8.960	.8
.9	.002817		2.989	8.997	.9
25.0	0.002828	0.2413	3.001	9.033	25.0
.1	.002840		3.014	9.070	.1
.2	.002852		3.027	9.107	.2
.3	.002865		3.040	9.145	.3
.4	.002877		3.053	9.182	.4
25.5	0.002889	0.2413	3.066	9.219	25.5
.6	.002901		3.078	9.256	.6
.7	.002913		3.091	9.293	.7
.8	.002926		3.104	9.331	.8
.9	.002938		3.117	9.368	.9
26.0	0.002950	0.2413	3.130	9.405	26.0
.1	.002962		3.143	9.442	.1
.2	.002975		3.156	9.480	.2
.3	.002987		3.170	9.517	.3
.4	.003000	0.2414	3.183	9.555	.4
26.5	0.003012	0.2414	3.196	9.592	26.5
.6	.003024		3.209	9.629	.6
.7	.003037		3.222	9.667	.7
.8	.003049		3.236	9.704	.8
.9	.003062		3.249	9.742	.9
27.0	0.003074	0.2414	3.262	9.779	27.0
.1	.003087		3.276	9.817	.1
.2	.003100		3.289	9.855	.2
.3	.003113		3.303	9.893	.3
.4	.003126		3.316	9.931	.4
27.5	0.003139	0.2414	3.330	9.970	27.5
.6	.003151		3.344	10.01	.6
.7	.003164		3.357	10.05	.7
.8	.003177		3.371	10.08	.8
.9	.003190		3.384	10.12	.9
28.0	0.003203	0.2414	3.398	10.16	28.0
.1	.003217		3.412	10.20	.1
.2	.003230	0.2415	3.427	10.24	.2
.3	.003244		3.441	10.28	.3
.4	.003257		3.456	10.32	.4
28.5	0.003271	0.2415	3.470	10.36	28.5
.6	.003284		3.484	10.39	.6
.7	.003298		3.499	10.43	.7
.8	.003311		3.513	10.47	.8
.9	.003325		3.528	10.51	.9
29.0	0.003338	0.2415	3.542	10.55	29.0
.1	.003352		3.557	10.59	.1
.2	.003366		3.572	10.63	.2
.3	.003380		3.586	10.67	.3
.4	.003394		3.601	10.71	.4
29.5	0.003408	0.2415	3.616	10.75	29.5
.6	.003422		3.631	10.78	.6
.7	.003436		3.646	10.82	.7
.8	.003450	0.2416	3.660	10.86	.8
.9	.003464		3.675	10.90	.9
30.0	0.003478	0.2416	3.690	10.94	30.0
.1	.003493		3.706	10.98	.1
.2	.003507		3.721	11.02	.2
.3	.003522		3.737	11.06	.3
.4	.003537		3.753	11.10	.4
30.5	0.003552	0.2416	3.769	11.14	30.5
.6	.003566		3.784	11.18	.6
.7	.003581		3.800	11.22	.7
.8	.003596		3.816	11.26	.8
.9	.003610		3.831	11.30	.9

[See second preceding page]

Welding Carbon-Moly Pipe at Delray

Quality Control

By Sabin Crocker*

But limited information has been published on the welding of carbon-molybdenum pipe — a material which possesses several advantages which make it popular for use in the temperature range of 850 to 950 F. Carbon-moly steel is being used for the 865 lb, 910 F steam piping in the extension of Detroit Edison's Delray Station; consequently, it is possible to report on the company's experience in welding this piping material to supplement available data. . . . Advantage of the opportunity is taken in this and succeeding articles to describe also new welding practices and construction details adopted during the course of this piping project. . . . In the January HPAC, Mr. Crocker discussed prevention of air hardening, need of and procedure for preheating, and stress relief

THE disastrous results which might ensue from failure of a welded joint in high pressure piping dictate that every precaution be taken in guarding against such a possibility, both to protect personnel and as assurance against interruption to electric service. The complete snapping off of a joint in a large high pressure pipe would indeed be a major disaster, the results of which it is not pleasant to contemplate. Such a possibility is not wholly outside the picture, however, since conditions of severe shock sometimes occur both in boiler feed lines and turbine steam leads through sticking of a feed regulator or the sudden tripping off the line of a turbine. Whipping of the lines under these conditions has been known to assume alarming proportions, and any strength weld in such piping should be capable of sustaining heavy impacts. The development in a line joint of even a small crack sufficient to constitute a leak with potential failure of the weld if kept in service, would be at best a disquieting event which might cause an inopportune shut-down for repairs. Hence the necessity for insuring (1) that none but thoroughly competent operators practice pipe welding; (2) that their work be adequately supervised; and (3) that where feasible, particularly on new designs, pilot welds be examined either by non-destructive methods, or cut up and explored for flaws, lack of penetration, etc. Detroit Edison practice in these respects is discussed in ensuing paragraphs.

Qualification of Welders

Rigid qualification tests for operators still constitute the primary safeguard against practice of the art by those not sufficiently skilled. Initial qualification tests are prescribed by codes and casualty insurance companies, with periodic requalification tests to demonstrate that operators have not lost their skill. The American Welding Society in 1937 sponsored a new system of qualification tests which is summarized as follows in its "Welding Handbook": "Each manufacturer or contractor shall be responsible for the quality of the welding done by his organization and shall conduct tests not only of the welding *process* to determine its suitability to insure welds which will meet the required tests, but also of the welding *operators* to determine their ability to properly apply the procedure." The qualification tests for process are intended to provide adequate demonstration of soundness, tensile strength, and ductility for each material to which the process may be applied. In qualifying operators, the American Welding Society rules recognize soundness of deposited weld metal as the sole criterion of an operator's ability. Accordingly strength and ductility tests are left to qualification of the process, while nick-break and bend tests are concentrated upon for qualification of the operators.

The AWS system for both sets of qualification tests describes in full detail the way in which specimen welds shall be made for the purpose of obtaining test coupons, including shape and weight of parts joined, material, position in welding, and any other items characterizing the process. Complete descriptions of test coupons with the number of each sort required are specified, with directions for conducting the tests and the observations to be recorded. Acceptable minimum numerical values are not stated in the rules for procedure, although suggested values are furnished in an appendix as information for use where no code values are available. Where these suggested test results are not deemed wholly appropriate by any code body making use of these rules of procedure, other values can be established in its code. This general form of procedure has been adopted for welded pipe connections in the latest draft of the ASME boiler construction code, and is now under consideration by the ASA sectional committee on code for pressure piping for substitution in lieu of the somewhat different set-up used in its tentative code issued in 1935. In order to play doubly safe on piping connections between the boiler and the first valve, the boiler code committee has set up its requirements so that each operator must be qualified with both sets of tests. It so happens that Detroit Edison welders working on carbon-moly pipe at Delray were qualified by both sets of tests, since these men were called upon to do work coming under the boiler code as well as beyond the first stop valves. The photograph of test coupons from a qualification weld on carbon-moly pipe made to boiler code requirements shown in Fig. 1 gives a better idea of the nature of such tests than might be gleaned from purely a written description.

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Co-ordination and Adequate Supervision Essential

The fact that Detroit Edison carries on its own design and construction work as well as producing and marketing electricity offers unusual opportunity for closely co-ordinating all phases of these activities. Trial in shop or plant of new welding details evolved by the company's engineers or designers is thus facilitated so that good ideas can be adopted promptly, while those which do not work out so well can be modified or abandoned. Then, too, integrated responsibility within a single organization affords better opportunity for controlling the quality of workmanship, and at the same time has the advantage of building up among the office and field forces a familiarity with company practice obtained through continuing the same men on successive projects. Under these circumstances welding can be carried on to best advantage with a construction force in which there are qualified operators, a welding supervisor or foreman, and a welding engineer.

A qualified operator on high pressure piping must of necessity be an artisan with unusual proficiency attained through long practice on less particular work. He must have been duly qualified by rigorous tests for welding in all the positions and with the particular base metal and electrode to be encountered on the job. Only a couple of operators need be qualified for field welding carbon-moly pipe joints on a job like the Delray extension, since the total number of such joints is few and the work usually can be spread over a considerable period of time. A larger group of operators qualified for field welding medium carbon (0.25 to 0.35 per cent carbon) steel pipe is required for high pressure boiler feed, saturated steam, blow off, and drip lines. There is a third group of operators who are qualified for welding low pressure lines of ordinary low carbon (about 0.10 to 0.20 per cent carbon) pipe. Some of these operators are engaged from time to time on shop fabrication of piping assemblies of the corresponding grade of material on which they were qualified for position welding. Welding operators of the first and second groups have their helpers who clean and chip each successive layer and render general assistance to their operators. In the third group the operators do their own cleaning and chipping.

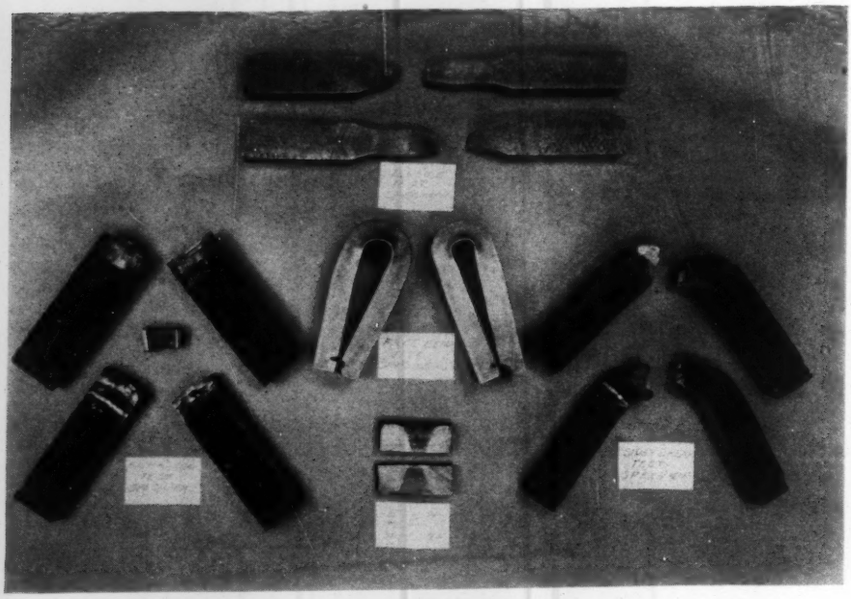
A welding supervisor generally develops from a welder, due to a combination of better training, more skill, and organizing ability. His function is that of foreman, assigning work to the operators and pushing production. The desire to keep down costs and get work out on time, however, is not allowed to obscure his sense of responsibility in maintaining quality and seeing to it that specified routine procedure is faithfully carried out. In supervising production he should satisfy himself that sound welds are produced, and that any beads suspected of containing flaws are chipped out and done over.

The welding engineer functions in a different way.[1] While he is in continual contact with production operations, his work is mostly advisory and of a liaison character between office and field. In this capacity he is the connecting link between actual welding and the engineers or designers who are eager to learn how their new ideas on improved details or methods of fabrication panned out. Thus the welding engineer is in the middle, so to speak, where he can transmit the office viewpoint to the field and the field viewpoint to the office, and at the same time be favorably situated for constructive contribution of his own at both ends of the line.

With welding, as in the case of other items, the functioning of the various phases of design and supervision along with actual construction within the fold of the same company that operates the completed plant has been conducive toward well conceived designs executed in a workmanlike fashion. A large measure of responsibility for The Detroit Edison Co.'s plant design is placed on the operating staff heads. The organization of a project such as the Delray extension is so devised that the men charged with the operation and maintenance of the company's existing plants, and who will have similar authority over the new plant when put into service, exercise a co-ordinating and directive control over the entire project from its inception to determination of the last detail. It is largely because of this fact that the completed plants closely reflect the day-to-day operating experience of the men who have to make the equipment function—which incidentally insures prompt acceptance of new construction by the plant force taking it in charge.

It is also of interest that Detroit Edison has its own drafting and construction force of experienced men who have been engaged for years on successive projects and are thoroughly versed in company practice. Work by the drafting and construction bureaus

Fig. 1—Test coupons on a qualification weld on carbon-moly pipe made to meet boiler code requirements
Top, tensile test. Center, free bend. Bottom, etch test. Left, nick-break. Right, side-break.

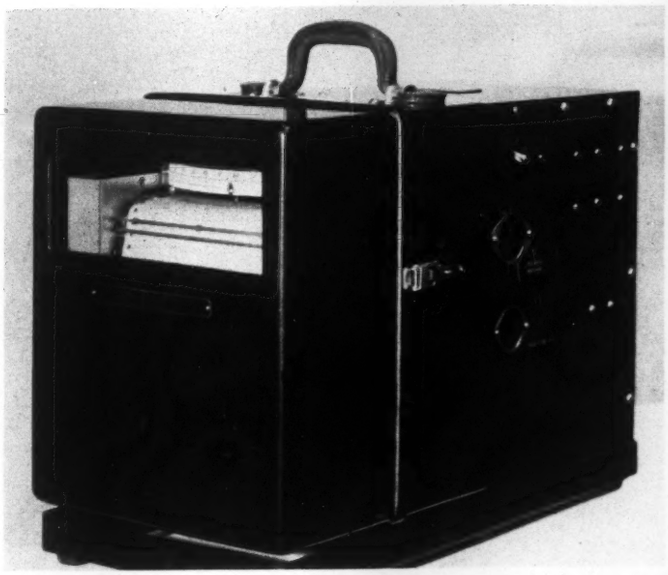


[1]See also "An Attempt to Define the Job of Welding Engineer," by R. Kraus in *The Welding Engineer*, December, 1937, for a more detailed conception of the needed qualifications. While Mr. Kraus is working in a somewhat different field with Stacey Brothers Gas Construction Co., his basic conception of the job agrees well with the way it works out with Detroit Edison.

is carried on for, and under the direction of, the various operating departments as if they were owners who had engaged an outside contracting firm to execute both design and construction. There is no separately organized engineering department responsible as such for planning and approving new work, although the company does have a central engineering division which advises various departments in a consulting capacity.

Use of the Arcronograph

Throughout the Conners Creek rebuilding project and the extension of the Delray plant, arcronographs[2] (see Fig. 2) have been used as an inspection aid to insure having operators deposit weld metal under uniform conditions which have been predetermined as yielding best results for the process in use. The fact that the operator works under the constant supervision of a graphical record and cannot hide his mistakes is considered a unique advantage of this instrument, sufficient to justify its use for psychological reasons alone if the instrument served no other useful purpose. Actually, however, the results are deemed more readily indicative of uniform quality workmanship, or the lack of it where the operator's performance is spotty, than are those obtained by radiography of field welds in piping.



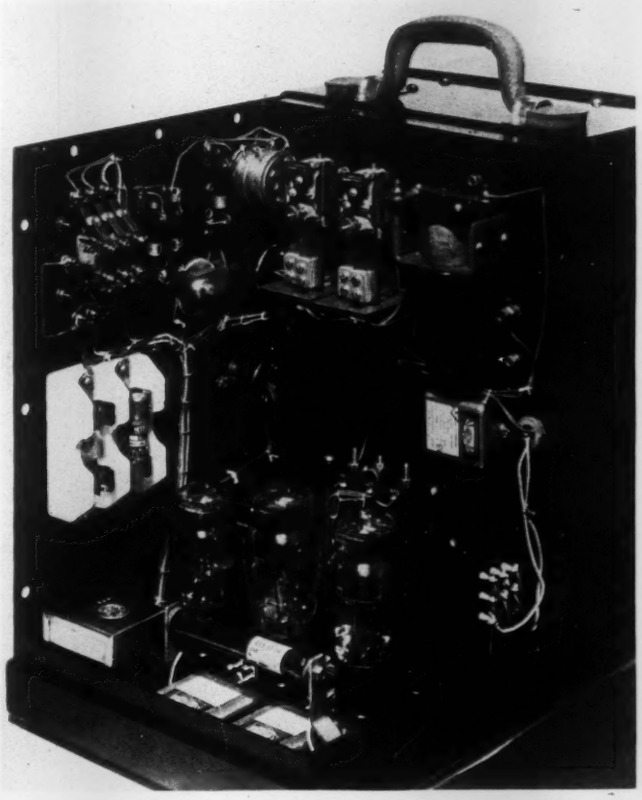


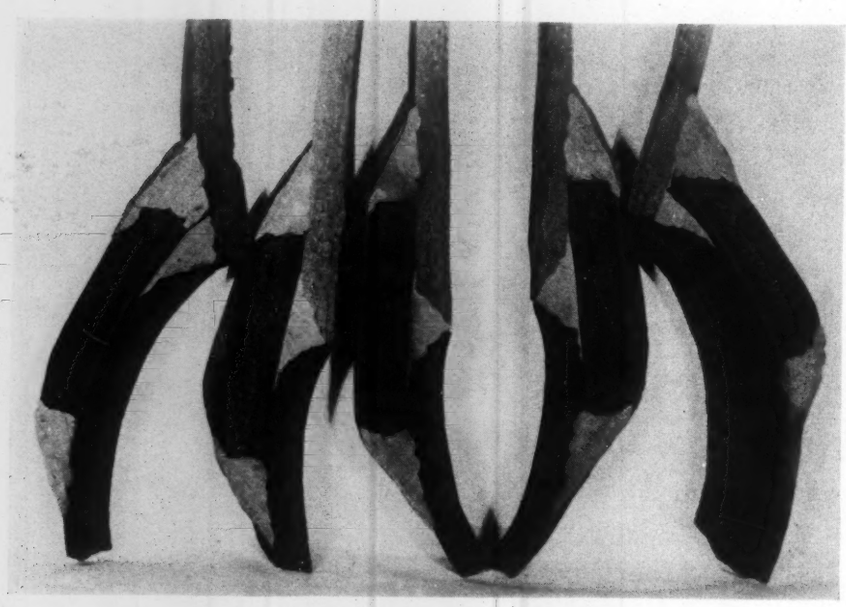
Fig. 2—Improved model arcronograph used for quality control. Exterior view shows indicating scale, recording chart, and receptacles for attachment cords. Interior view shows rectifier tube with two other vacuum tubes, relays, resistors, etc., in the various electrical circuits.

While excessive porosity or lack of penetration of the bottom of the vee sometimes can be detected by radiography, using either x-rays or gamma rays, the results obtained are not always so dependable as might be desired, especially in examining branch outlets and other irregular shapes. Radiography, of course, yields only shadow pictures in which the presence of a defect is merely suggested by a difference in the intensity of the shadow—there is nothing so decisive as, for instance, an x-ray in the medical field showing the safety pin in a baby's stomach. Due to this limitation, plus physical restrictions on the number of shots which can be taken in triangulating on a weld to discover defects, it is quite possible for flaws to pass unnoticed in radiograph examination of a weld in assembled piping. That such is the case has been demonstrated conclusively by failure of commercial x-ray methods to locate more than half of the artificially induced defects in an experimental weld submitted for such examination.[3]

Subsequent investigation has indicated that failure to detect flaws often can be attributed to faulty technique, rather than to inherent lack of fitness of x-ray examination itself. This lack of absolute, definite certainty in detecting flaws, coupled with the high cost and inconvenience of radiographic examination of piping, either in shop or field, has inclined the company's engineers to rely on the arcronograph for routine check, and to confine the use of radiography to laboratory exploration of new designs in verifying their soundness. Even in this field when thoroughgoing exploration of a new design for soundness and full penetration is required, the company's engineers feel that there is nothing so informative as sectioning a pilot specimen into thin slices

[2]For a complete description of the instrument and a discussion of the theory on which it operates, see "The Evolution of the Arcronograph" by Bela Ronay, *Journal* of the American Society of Naval Engineers, August, 1934. Briefly, the instrument employs a three element vacuum tube to take account of the ratio of arcing time to short circuiting time in the process of depositing each globule of weld metal. Since this ratio should be essentially constant for a given size and type of electrode, the graphical record serves to show how consistently the operator has performed in laying on each bead. Satisfactory limits for the graphical record produced when using any given electrode are set initially through observing the range of chart values obtained while doing test work which is known to be satisfactory. If in actual welding the graph swings outside the predetermined limits, that portion of the work is then subject to suspicion and due for examination. Any flaws in the bead thus become apparent as the work proceeds and can be chipped out or otherwise corrected while the bead is still exposed without having to wait for an x-ray or other examination of the completed weld.

[3]See *Mechanical Engineering*, March, 1938, pp. 258-259 for discussion by D. H. Corey of ASME paper by H. R. Isenburger on "Radiographical Inspection."



a *b* *c* *d* *e*

Fig. 3—Sections from branch connection of a welded manifold cut up for observation

and really having a look at what exists inside a typical weld.

Sections of this sort from the reinforced branch outlet of a welded manifold made for test purposes are shown in Fig. 3. Observation of these sections served to point the need for corrective measures in both design and execution in order to overcome such deficiencies as lack of full penetration to bottom of scarf or fillet as manifest in sections *a, b, d;* imperfect fusion of weld metal to parent metal in sections *c, e;* no attachment of reinforcing weld to initial weld in section *a.* Measures taken to overcome these deficiencies will be discussed in an article by Arthur McCutchan to appear in a future issue of HEATING, PIPING AND AIR CONDITIONING.

To acquire experience in interpreting arcronograph charts, further use was made of these instruments for experimental and operator-qualification test welds. Since all such welds are subjected to destructive tests in determining physical properties, including soundness, this practice afforded opportunity for correlation between weld properties and arcronograph charts which could not be had in regular field construction. A striking difference was noted in the appearance of charts produced by welders whose work met the requirements of the qualification test as to physical properties and of those whose welds did not meet the requirements.

A further correlation was observed between the amount of gas pockets (porosity) present and the uniformity of the arcronograph chart. Even good welders are prone to produce some gas pockets, but with poor operators the extent of these flaws may become objectionable without sufficiently affecting the physical properties as to be detectable on that score alone. Hence, in the qualification tests of most codes, requirements are provided for specific gravity and permissible number and size of gas pockets per square inch of weld metal. The number of interruptions in depositing electrode metal, or pauses to chip out defects before finishing an electrode, are bound to be reflected in the number of gas pockets present in the weld.

One of the advantages of the arcronograph is that it affords a graphical record of such interruptions as well as the extent to which the operator lets the electrode waver during the progress of his work. These tendencies are exhibited in the three specimens of arcronograph charts presented in Fig. 4 of which Chart *A* is typical of a sound weld for this particular process. Deposition of two complete electrodes and parts of two others are shown, the three full scale deflections being interruptions for changing rods. Chart *B* is marked by a succession of starts and stops, with short intervals of satisfactory welding. Chart *C* is extremely ragged, with even shorter intervals of sound welding.

While the physical properties of all three welds were satisfactory from the standpoint of strength and ductility, only *A* was acceptable on the score of gas inclusions. Since the absence of gas pockets has been found about the best criterion for judging comparative skill among a group of welders, the insight afforded by an arcronograph chart on conditions within a weld is deemed of significant value in establishing consistently good performance. Qualification tests alone are not considered sufficient guarantee of uniform results from day to day for even a good operator on account of the human factor involved; hence the need for an instrument which will continuously detect and record inferior performance on the part of either a good or poor welder.

Although the principle on which the arcronograph operates has been reported in some detail, the question frequently is raised as to why simple recording instruments such as ammeters, voltmeters or wattmeters would not give as satisfactory results. The reason is that such meters respond to incorrect welding conditions, such as unduly long or short arc or wavering hand action, only in proportion to the actual change in arc current or voltage. In this connection R. W. Clark[4] has remarked that in his investigations "no defects were found corresponding to the irregularities in the arc voltage records" as determined with a recording voltmeter. The arcronograph, however, exaggerates defects by giving a full-scale deflection whenever welding conditions are not within predetermined limits as fixed by relay settings. Furthermore the ordinary recording meter, unless supplemented with auxiliary equipment, produces a continuous chart throughout the day. Under field welding conditions, only a small part of the elapsed time devoted to a joint is spent in actually depositing weld metal. Hence the provision whereby the arcronograph is operative only during actual welding greatly reduces the amount of chart to be handled.

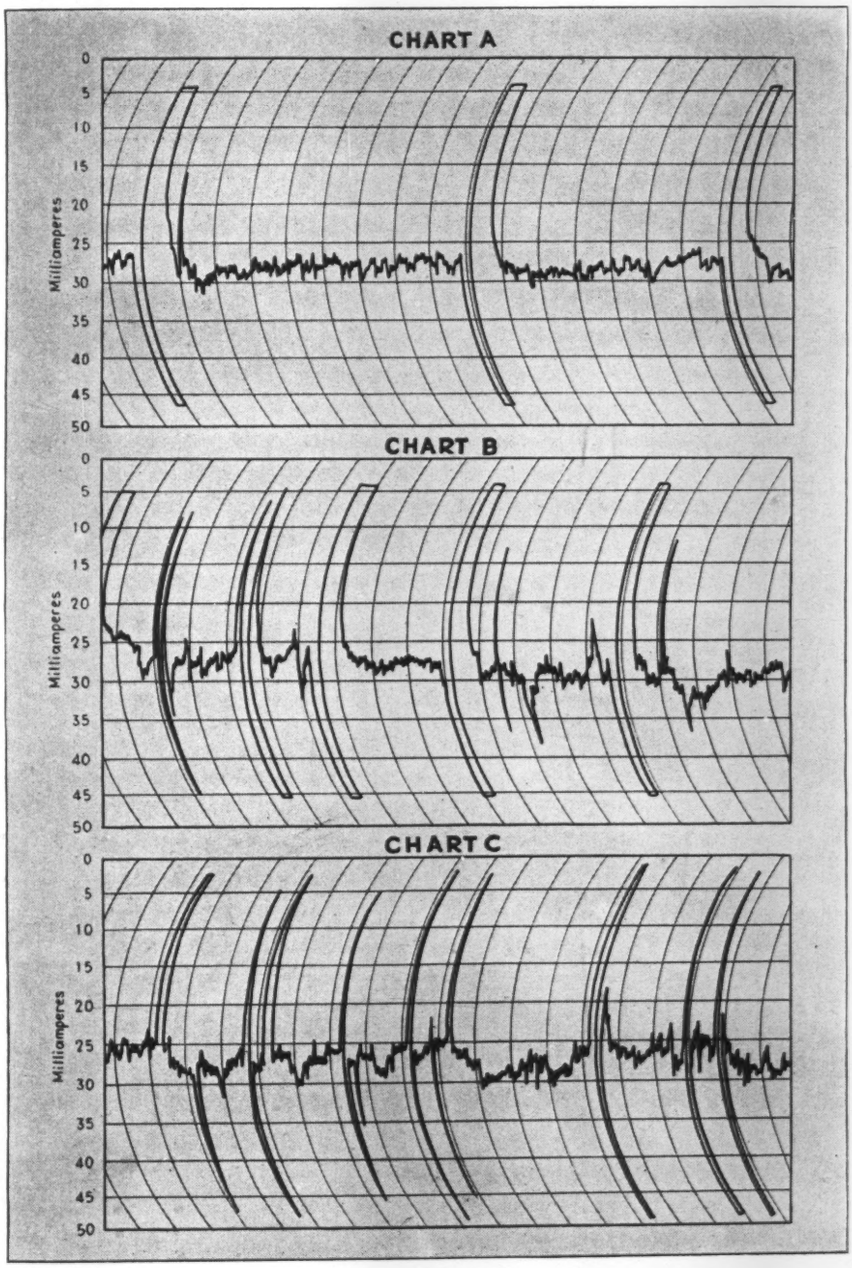
It may be something of a surprise to many to learn,

[4] "Welded Joints in Carbon-Molybdenum Piping," by R. W. Clark, HEATING, PIPING AND AIR CONDITIONING, November and December, 1938.

as shown by the arcronograph charts of Fig. 4, that a good welder takes only about one minute to deposit a whole electrode rod, at the end of which time the operation has to be interrupted while another rod is fastened in the holder. Hence shutdowns come too frequently to warrant having to start and stop the recording device by hand.

[Note: Mr. Crocker's article in January, and this article, have reviewed Detroit Edison welding practice and explained refinements made to suit more exacting requirements in welding carbon-moly pipe. Future articles by Arthur McCutchan of the same company will set forth new practices and improved details for items such as welding ends for pipe and valves, tapered backing rings, and the beveling of welded branch connections so as to permit the application of contoured backing rings.—EDITOR.]

Fig. 4—Typical good and bad arcronograph charts obtained during qualification tests of different welders. *A*—Typical record for sound weld. *B*—Mediocre welding with a succession of starts and stops. *C*—Inferior welding with still more frequent interruptions than in *B*



Check Charts for Air Conditioning Calculations

By J. M. Dean*

ON THE next page are published Charts Nos. 15 and 16 of a series, the first of which appeared in the May, 1938, HPAC with a general introduction. These charts were developed in connection with the author's duties as air conditioning engineer for an electric utility in an endeavor to reduce the work of checking air conditioning calculations to a simple routine procedure. Chart 15 is for figuring lb per min and cfm of air through coils and bypass, and Chart 16 is for making capacity checks.

*Air Conditioning Engineer, Des Moines Electric Light Co.

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Standard for Welding Fittings

A draft of a proposed American Standard for welding fittings has recently been completed by subgroup No. 6 on welding fittings of subcommittee No. 3 on steel flanges and flanged fittings of sectional committee B16 on the standardization of pipe flanges and flanged fittings. This proposal covers the over-all dimensions of fittings as designed for butt welded joints, such as elbows and tees, caps and lapped joint stud ends, reducers, and return bends. It covers also the pressure ratings, size, marking, material, metal thickness, tolerance, and welding bevel. This proposal is now being distributed to industry for criticism and comment. Copies are available on application, and communications should be addressed to C. B. LePage, Assistant Secretary, American Society of Mechanical Engineers, 29 West 39th St., New York, N. Y.

The standardization of welding fittings is a part of the project assigned to the sectional committee on the standardization of pipe flanges and fittings of which Dr. Collins P. Bliss is chairman and J. J. Harman is secretary. The committee was organized under the procedure of the American Standards Association in 1921 with the Heating, Piping and Air Conditioning Contractors National Association, the Manufacturers Standardization Society of the Valve and Fittings Industry, and the American Society of Mechanical Engineers, as joint sponsors. In all, 30 national organizations are cooperating in this project.

Check Charts for Air Conditioning Calculations

[See preceding page]

Chart No. 15

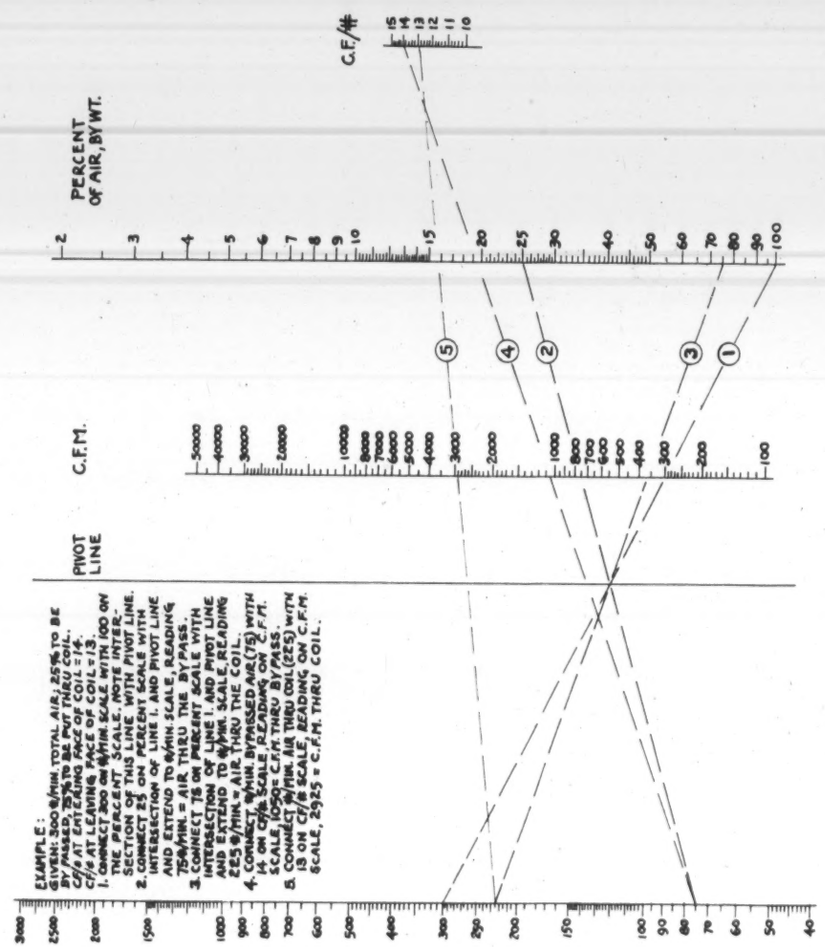
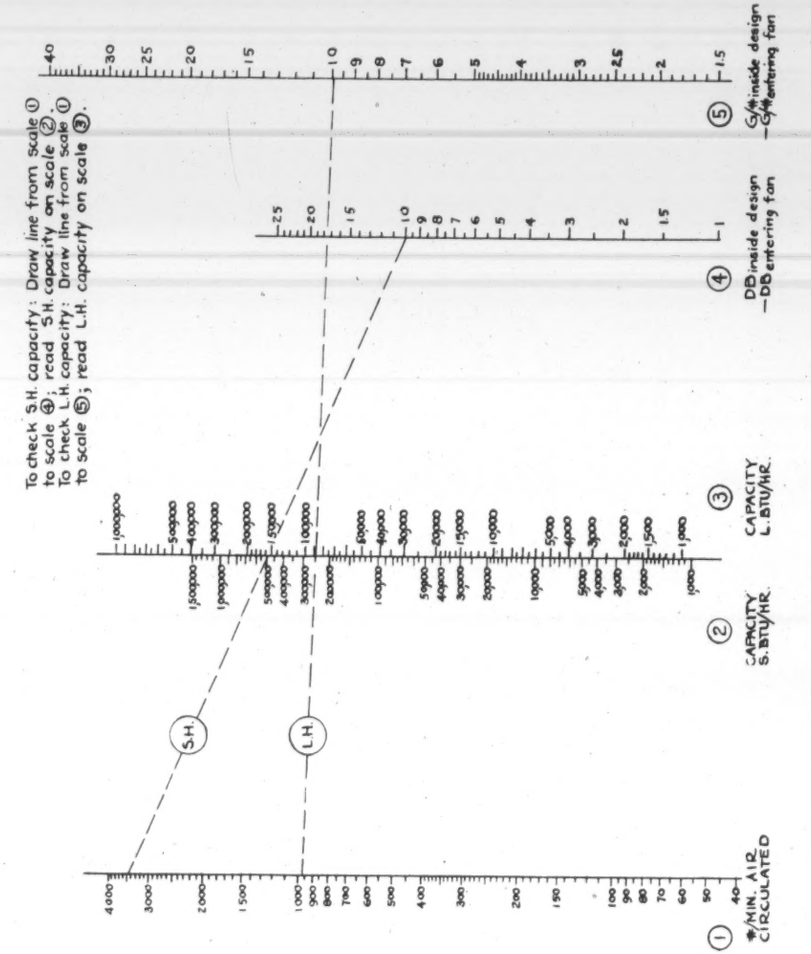

#/MIN. AIR
PIVOT LINE
C.F.M.
PERCENT OF AIR, BY WT.
C.F./#
EXAMPLE:
GIVEN: 300 #/MIN. TOTAL AIR, 25% TO BE BY-PASSED, 55% TO BE PUT THRU COIL.
BY-PASS FACTOR OF COIL = .15.
C/A AT LEAVING FACE OF COIL = 13.
1. CONNECT 300 on #/MIN. SCALE WITH 100 ON THE PERCENT SCALE. NOTE INTERSECTION OF THIS LINE WITH PIVOT LINE.
2. CONNECT 25 ON PERCENT SCALE WITH INTERSECTION OF LINE 1. AND PIVOT LINE AND EXTEND TO #/MIN. SCALE, READING 75 #/MIN. = AIR THRU THE BY-PASS.
3. CONNECT 13 ON PERCENT SCALE WITH INTERSECTION OF LINE 1. AND PIVOT LINE AND EXTEND TO #/MIN. SCALE, READING 225 #/MIN. = AIR THRU THE COIL.
4. CONNECT #/MIN. BY-PASSED AIR (75) WITH 14 ON C/A SCALE, READING ON C.F.M. SCALE, 1050 = C.F.M. THRU BY-PASS.
5. CONNECT #/MIN. AIR THRU COIL (225) WITH 13 ON C/A SCALE, READING ON C.F.M. SCALE, 2925 = C.F.M. THRU COIL.

Chart No. 16


To check S.H. capacity: Draw line from scale ① to scale ④; read S.H. capacity on scale ②.
To check L.H. capacity: Draw line from scale ① to scale ⑤; read L.H. capacity on scale ③.
#/MIN. AIR CIRCULATED
CAPACITY S.BTU/HR.
CAPACITY L.BTU/HR.
DB inside design —DB entering fan
G/# inside design —G/# entering fan
S.H.
L.H.

Restaurants Store Refrigerating Effect for Use During Peak Conditioning Loads

By Lester T. Avery*

WHILE there is nothing new about freezing ice on coils, the use of ice water and storage ice for air cooling does present out-of-the-ordinary problems. Two restaurant installations employing the storage of refrigeration effect for air conditioning were designed by the author and completed recently, from which pertinent data are available.

In order that the reader may better understand the type of cooling load involved in these particular systems, it is necessary to review how these jobs—like Topsy—"just grew." During the summer of 1935 a modern restaurant situated in the center of downtown Cleveland installed an ice-using air cooling system. The restaurant at that time had a complete ventilation system with a 6000 cfm fan handling filtered air which was drawn through blast heating coils. This was used for heating in winter and ventilation all year.

The author was recently responsible for changing over two ice-using cooling installations in restaurants to mechanical compressor jobs so arranged as to store refrigerating effect for use during periods of peak air conditioning loads by freezing ice on coils installed in the water cooling tank. . . He describes the reasons for making the changes and gives practical suggestions on design, installation, and operation

The water circulating cooling coils (parallel flow copper tube and fin coils with cast iron headers) were placed in the casing of the air unit. The coils were arranged in two sections high, each four rows deep, and the face velocity was about 500 fpm. The ice tank was approximately 9 ft long, 7 ft wide, and 6 ft high, and the water circulating pump had a capacity of 50 gpm. Ice was purchased and stored in the tank; the water was circulated from the pan under the ice rack through the coils, the return water being sprayed over the top of the ice. This system worked very satisfactorily, although it used about twice the amount of ice which it was estimated would be required at the time the installation was made.

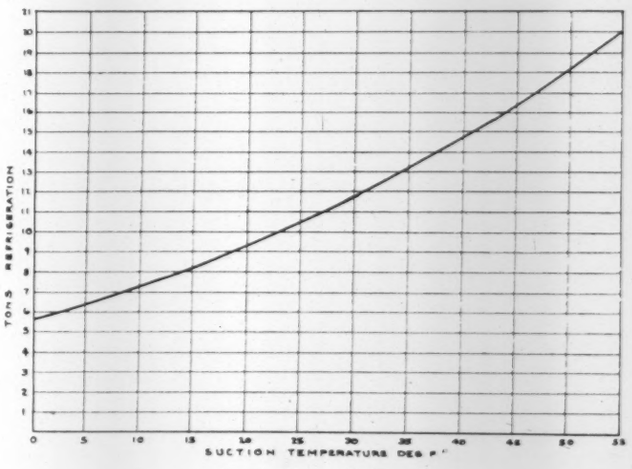
An additional air conditioning system was installed the following year to serve the counter section of the restaurant only, which is open continuously from 8:00 a. m. to 8:00 p. m. This consisted of an entirely separate air conditioning unit with supply and recirculating ducts for the counter section. The unit had a capacity of 3000 cfm and was equipped with a water circulating cooling coil with an automatic valve controlled from a thermostat in the return air. It was thought that this would afford considerable ice economy and greater flexibility. The main restaurant, seating 200 people, is open only from 11:00 a. m. to 2:00 p. m., and from 5:30 p. m. to 8:00 p. m. By shutting down the main system when the room was not open to the public, the counter system would carry its load for 50 people without waste of ice. The supply and return grilles were situated in such a way that the two rooms operated entirely independently of each other, although there was a 20 ft by 8 ft opening between them.

This change made considerable improvement in the operation of the counter section, which had not been getting sufficient air. There was still an excessive cost of ice for air cooling, however. The system operated through the summer of 1936 in this manner, using about 320 tons of ice, and the same operation was continued through the summer of 1937.

The 1937 season in Cleveland was not extraordinarily hot, but the system did not produce satisfactory results. Plenty of ice was used, and the ice water was circulated the same as before, but it was not until the end of the season that the difficulty was discovered—an accumulation of slime and dirt from the melting ice that had practically stopped up the inside of the coils, giving them a very poor heat transfer coefficient and restricting the flow of water. The coils were cleared by removing the headers and running a small tube cleaner through them. Then a solution of tri-sodium phosphate was mixed in the tank and the entire piping system flushed out for 24 hours. The solution was removed, with bucketsful of sludge, and then the piping, tank and coils were rinsed out with fresh water. A preliminary test in the early spring with cold city water showed that the coils had once again regained their efficiency.

The owners were still interested in reducing the operating cost; that is, the actual cost for summer air conditioning for the people served. With an investment

Fig. 1—Change in the compressor capacity as the suction temperature drops due to freezing of ice on coils



*President, Avery Engineering Co.

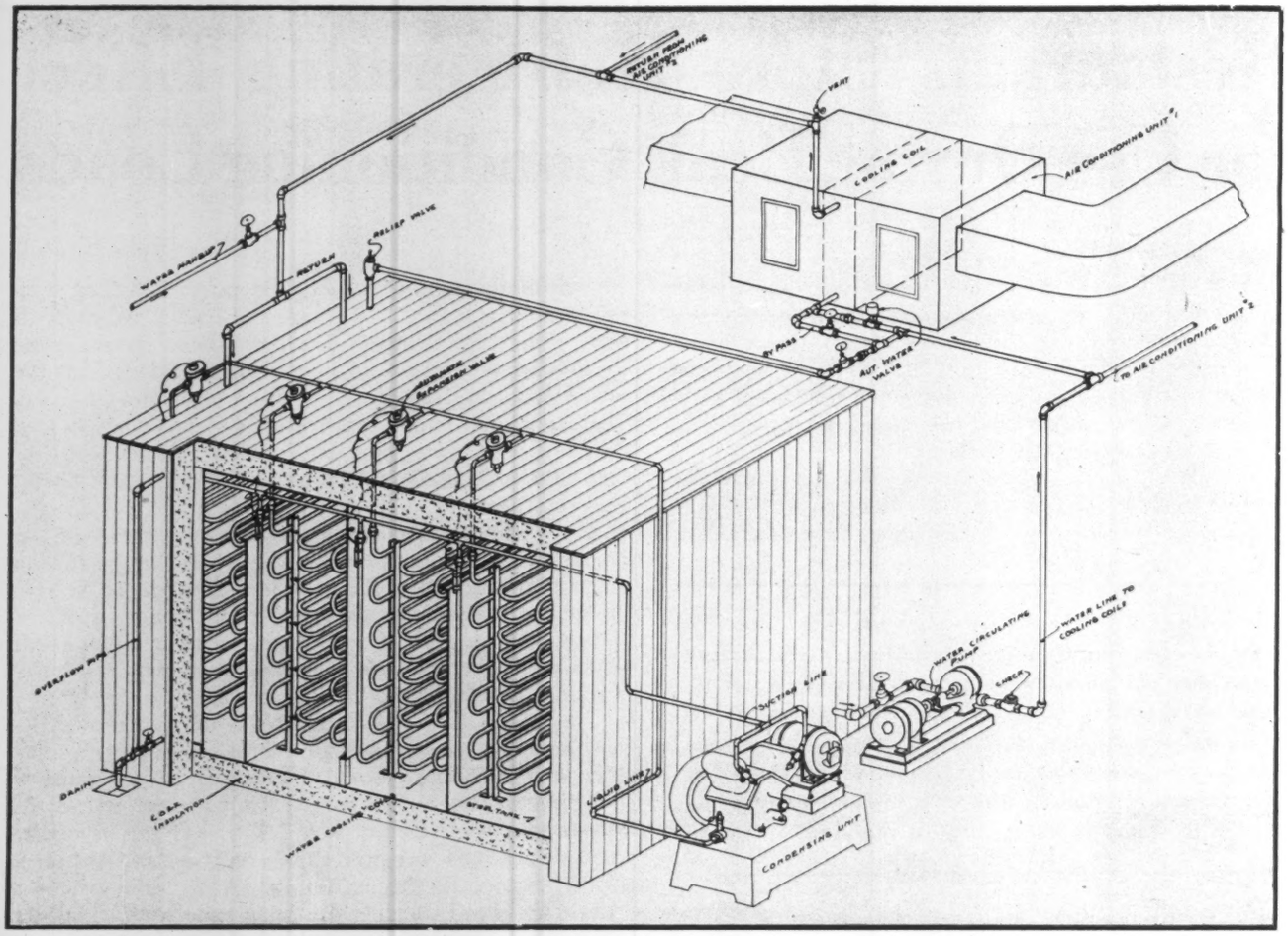


Fig. 2—Diagram of system storing refrigeration for air conditioning service by freezing ice on the coils in the tank

of about $3000 for a refrigerating machine using a 15 hp motor, and an operating cost estimated at $400 per season, it was estimated that a refrigeration plant (instead of ice) would pay for itself in from three to four years. Another way of analyzing the cost indicated a return of 30 per cent on the investment for such a plant.

Careful check showed that the counter section required a continuous cooling load varying from 3 to 7 tons capacity, and the main restaurant an intermittent load of 10 to 20 tons. This 20 ton maximum load was extremely variable, starting with a minimum of people at 11:00 a. m. and building up to a peak between noon and 1:30 p. m. This air system could be shut down entirely after 2:15 p. m. and started again around 5:30. The peak load in the evening would not build up to the full combined 27 tons (probably more nearly 16 tons) but still well over the capacity of the proposed 15 hp machine.

It is well known in refrigeration practice that the machine capacity drops off with a decrease in suction temperature (or pressure), and in order to freeze and store ice the machine would have to run at a low suction. Referring to the manufacturer's tables for the compressor selected, the machine rates at 15 tons capacity with 40 F suction, 12 tons capacity with 30 F suction, and at 9½ tons at 20 F suction. The curve of Fig. 1 shows the change in the machine capacity as the suction pressure drops due to freezing ice on the coils. From this curve calculations were made for each hour of restaurant operation to show how much ice could be stored in the tank between peak loads on the air cooling. There is 144 Btu available from every pound of ice melting from and at 32 F, but only 8 Btu per lb available when the resulting water warms from 32 to 40 F. For economy in space, therefore, ice must be frozen for storage capacity.

An automatic water valve was installed on the main system air cooling coil and connected to a thermostat in the restaurant. The machine was installed with automatic control to hold about 1½ in. of ice on the coils, which is equivalent to 1½ tons of ice. The water circulation through the tank was designed so that the water would continue to circulate over all coils even though they were well covered with ice. The original ice storage tank served as the space for the direct expansion "Freon-12" coils, and by filling this tank with water for storage, the mechanical system was installed with a minimum first cost for the change-over from the ice system.

In actual operation the system has functioned about as planned, although less hours of operation are required. In hot weather the machine operates continuously for about 15 hr; in moderate weather the load drops off to require an intermittent operation totaling about 10 hr. The system maintains 33 F delivered water temperature continuously, as even under peak conditions there is always ice in the tank. This cold

water has served to give excellent dehumidifying in the restaurant, so that actually the conditions are superior to those secured previously with 40 to 50 F water. The operating cost for the season has been less than was figured, and the investment should prove self-liquidating in less than three years.

Another ice installation in a larger restaurant figured 45 tons peak capacity for three hours, twice a day, and had been using 450 tons of ice per season. This installation was changed over to a 25 hp "Freon-12" machine. This was a 450 seat restaurant that originally had one central system with ice tank, 75 gal pump, and water coils. An additional wing had been added after the original installation and an additional unit cooler had been connected to the water circulation system, but no change was made in the pump. There was no automatic control and cooling was either on or off with the water pump operation.

This air conditioning system was handicapped by insufficient water pumping capacity, and an additional water pump was planned. The return water on this system passed through a header system with sprays showering the water over the ice, which required the pump to operate at 30 lb gage pressure. By removing some of the spray heads and allowing a freer flow of the water returning to the tank, the pressure was dropped to 18 lb. This increased the pump capacity by one-third, and it was found unnecessary to add the auxiliary pump.

The mechanical system maintains ice storage right through the peak load period, delivering 35 F water which is returned to the tank at 45 F. Here again the air conditions in the restaurant were greatly improved as compared with the former system. The investment of $4000 for the mechanical equipment should be retired in about three years.

Entirely aside from the question of operating cost are the indirect advantages of maintaining clean coils at all times and economical, automatic control of temperature and humidity in the space. From a power cost standpoint this method uses a small compressor motor at a lower demand charge and increases the machine operating hours over a longer period than would a plant not employing the storage principle. Some power companies claim this is a very desirable type of load.

Unfortunately it is not usually economical (in my experience) to plan a new installation on this same refrigeration storage basis. It is cheaper to install a larger refrigerating machine with direct air cooling coils than to use the smaller machine with the additional cost for the ice tank, insulation, water pump, water piping, and ice freezing coils. In some locations where connected motor horsepower is limited by the available power lines, or where there is a severe penalty for high demand in short periods, this storage system may prove economical as an original installation. Also, where an indirect system is required by code the storage method would be practical. In the particular cases above described, the ice tank, pump, and piping were all in and could be used to full advantage with the refrigerating machine.

The coils used in both of these water cooling tanks consist of 1¼ in. full weight steel pipe arranged in sections for minimum gas pressure drop, and each coil is served by a thermal expansion valve. It is particularly important to distribute the water through the tank in such manner as to get uniform circulation and full effectiveness from all coil surface, as the water has a tendency to short circuit. It has been found possible to have a delivered water temperature of 45 F when half the coils are still covered with ice, simply because the warm return water does not thoroughly mix with the water in the tank to get the full effect of the ice melting.

It is not practical on such change-overs to figure the machine load required on the basis of the previous ice consumption, as it is often the case with an ice system to run short. When the tank is originally filled with ice the water temperature drops to a minimum of 33 F and as the ice melts, the pieces become smaller until near the end of the operating period there is very little ice left in the tank and the water temperature has risen to 55 or 60 F. The owner feels that this is necessary in order to economize on ice cost, as it seems a waste to leave several thousand pounds of ice in a tank overnight, for instance, when the system will not be operated until 10 o'clock the next morning. The more correct way to figure the load is to take into account all heat gains from people, lights, ventilation, etc., just the same as if there were no previous record of ice consumption. When this load is checked against the ice actually purchased, it may show about 25 per cent more ice *should have been used*. The temptation, of course, is to install a compressor that will give the same cooling effect as the ice has been giving, but once an automatic refrigeration system is installed, it is expected to function 100 per cent. There is little complaint if the machine is slightly oversize.

There are two statements in an earlier article[1] on storage refrigeration which are not confirmed in experience with the two installations decribed above. First, there appears to be no need to regulate water to the coils with a mixing valve to hold 40 to 45 F. If 40 F coil temperature is used in the design, more surface is required than for 33 F temperature. On the installations described here, the automatic throttling valve controls the *quantity* of 33 F water into each coil according to room temperature. Observation shows that dehumidifying is better this way than with higher temperature water, although actual temperature of delivered air is held constant.

The second observation is that no difficulty is experienced in operating the machine with a tank full of warm water. After shutting down over Sunday, the water temperature is up to 60 or 70 F and the machine operates at 35 lb suction. As the water cools the suction pressure drops until with a full storage of ice 1 to 1½ in. thick the suction pressure is down to 20 lb. No difficulty is encountered with the machine cutting out with high pressure; in fact, discharge pressure remains constant at 115 to 120 lb. The low pressure control is set to cut out at 16 lb.

In conclusion, the following things should be checked in converting an ice using system to a mechanical refrigeration storage job: (1) Cleanliness of air cooling water coils, *inside* and outside. (2) Quantity of ice storage to be frozen on the coils to carry over the peak air cooling load. (3) Uniform circulation of water over the coils in the storage tank. (4) Quantity and temperature of water circulated through air cooling coils. (5) Accurate survey of the actual air cooling load.

[1] "Storing Refrigeration for Air Conditioning," HEATING, PIPING AND AIR CONDITIONING, June, 1938, pp. 395-397.

The Real Cost of Refrigeration Piping

. . . is made up of both the initial capital cost and the cost of operating the system after the piping has been installed. Too small pipe sizes result in heavy penalties month after month, as shown here by R. C. Doremus*, who analyzes several examples. It is foolish, he points out, to jeopardize efficient operation of a refrigerating system by attempting to save by skimping on pipe sizes.

THE cost of a refrigeration piping system is composed of the initial capital cost of the installation and the cost of operating the system after the piping has been installed. There is a wide latitude in choosing pipe sizes, between making them plenty large for safety and designing for suitable velocities and friction pressure drops. The balance looks something like this:

Too Small a Pipe Size	Too Large a Pipe Size
Low initial investment	High initial investment
High pressure drops	Low pressure drops
High operating cost	Low operating cost

Obviously, there is a middle ground where the most economical pipe size may be determined in which the pipe size is not excessively large and expensive in initial cost and yet where pressure drops are not high and the operating cost is accordingly relatively low.

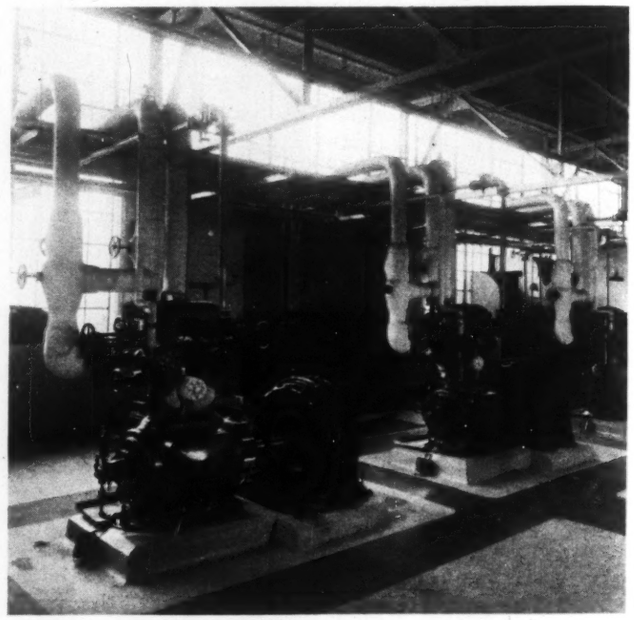
Suction Piping

It is here that the temptation to reduce initial costs is the strongest. The designer will probably try to make these lines as short and direct as is possible, and rightly so, but the use of too small a size of pipe for handling the gases will cause high gas velocities and friction drops which affect the operation of the refrigeration compressor adversely so far as pumping efficiency is concerned.

Let us consider a hypothetical case of an ammonia refrigeration plant in which the low side may be satisfactorily accomplished with a 26 lb suction pressure, which is equivalent to an evaporator temperature of 12.4 F. If the suction main has been properly designed, the suction line pressure drop will not exceed 1 to 1½ lb. In this case the refrigeration load could be handled with a pressure drop of 0.7 lb and so the suction pressure at the suction inlet of the compressor would be 25.3 lb in order to maintain an evaporator pressure of 26 lb.

If, however, the suction line is a long one with a large number of elbows, tees, etc., and is too small in size so that the suction vapor velocity is excessively high, the suction line pressure drop will be quite large. If it is 5.7 instead of 0.7 lb, the compressor will have to operate at a correspondingly lower suction pressure in order to still produce a pressure of 26 lb in the evaporator. This will also cause a superheating of the suction vapor due to both friction pressure drop and heat gain through the pipe and insulation in this long suction line. This requires the compressor to operate at a suction presure of 20.3 lb per sq in. gage. If the machines in the plant are horizontal, double acting ammonia compressors with a gross displacement of 1,000,000 cu in. per min and the condensing pressure is 145 lb per sq in. gage, two widely differing capacities will result. A simple comparison, Table 1, of these two conditions with the same plant load is interesting.

*Detroit Ice Machine Co. Member of Board of Consulting and Contributing Editors.



Three 9 in. by 9 in. ammonia compressors

Table 1 shows very clearly the result of using a suction main of too small a pipe size. The principal effect in this excessive friction pressure drop is the large loss in compressor capacity. If this is a plant serving a manufacturing process, the evaporator temperature of 12.4 F must be maintained regardless of pipe line conditions. If the total tonnage involved in the process is approximately 150 tons of refrigeration, it could be amply handled with the above mentioned compressors with the proper size suction main at a compressor suc-

Table 1—Comparative Data with Different Suction Pressures

	At Comp. Suct. Press. of 25.3 Lb	At Comp. Suct. Press. of 20.3 Lb
Evaporator suction pressure, lb per sq in.	26.0	26.0
Evaporator temperature, saturated, F	12.4	12.4
Suction line pressure drop, lb per sq in.	0.7	5.7
Compressor suction pressure, lb per sq in.	25.3	20.3
Condensing pressure, lb per sq in.	145.3	145.3
Suction vapor superheat, F	0	20
Refrigerating effect, Btu per lb	480.6	490.4
Weight of ammonia per min per ton, lb	0.4163	0.4077
Specific volume of suction vapor, cu ft per lb	7.047	8.409
Displacement required per min per ton, cu in.	5068	5927
Compression ratio	4.00	4.58
Volumetric efficiency, per cent	76.3	74.3
Compressor displacement, gross, cu in. per min	1,000,000	1,000,000
Compressor displacement, net, cu in. per min	763,000	743,000
Compressor capacity, net, tons of refrigeration	150.7	125.5
Indicated horsepower per ton	0.860	0.910
Indicated horsepower, total	129.6	114.2

Table 2—Costs with Proper Size Suction Main

Estimated cost of ammonia compressors and drives	$20,000.00
Estimated cost of ammonia piping and erection of all equipment and piping	6,500.00
Total	$26,500.00
Yearly amortization of all piping and compressor equipment based on a 20 year life	$ 1,325.00
Probable yearly labor cost	6,200.00
Probable yearly maintenance cost	300.00
Probable yearly power cost (165 hp @ $0.0125 per hp-hr)	18,067.50
*Total yearly cost	$25,892.50

*Note—This total yearly cost does not include the cost, maintenance or operation of any evaporator equipment or auxiliaries which might add some 25 per cent, but is here given simply for the purpose of comparison.

tion pressure of 25.3 lb per sq in. However, if some initial saving has been attempted in the piping and the suction main has been installed too small so that the compressors have to operate at a 20.3 lb suction pressure, their capacity has been decreased to 125 tons—which means that they are shy 25 tons of handling the total load.

The small suction main should be removed and replaced by a larger one of suitable size and capacity, but this is seldom done. The suction line has been installed and tested tight and it is human nature to leave it alone. Instead, another compressor of 25 tons capacity is installed to make up the shortage in performance and this is driven by a 40 hp motor, thus adding to the equipment as well as to the power load. The net result is that for each 1 lb pressure drop in the suction main, a loss of about 3 per cent is caused in compressor capacity, and in cases of plants that operate on still lower suction pressures for colder temperatures, such as ice cream or quick freezing of foods, the loss is still more marked.

The power angle has also been affected for, instead of requiring approximately 165 brake hp for the total load of 150 tons, or about 1.10 hp per ton, the required brake hp is now about 202, or 1.35 hp per ton. This represents an increase of 37 hp over the more efficient way of operating, or 22.2 per cent, or an increase of about 4 per cent for each 1 lb of suction pressure drop.

Thus, what seemed to be a saving in capital investment has not been a saving as contemplated. To the contrary, it has resulted in requiring a larger initial investment due to the additional equipment that had to be installed. The operating cost has also been increased due to the increased power requirement. A cost comparison, while hypothetical, might be set up somewhat as in Tables 2 and 3.

Table 3—Costs with Small Size Suction Main

Estimated cost of ammonia compressors and drives, including added 25 ton machine	$23,000.00
Estimated cost of ammonia piping and erection of all compressors and piping	6,800.00
Total	$29,800.00
Yearly amortization of all piping and compressor equipment based on a 20 year life	$ 1,490.00
Probable yearly labor cost	6,200.00
Probable yearly maintenance cost	350.00
Probable yearly power cost (202 hp @ $0.0125 per hp-hr)	22,119.00
**Total yearly cost	$30,159.00

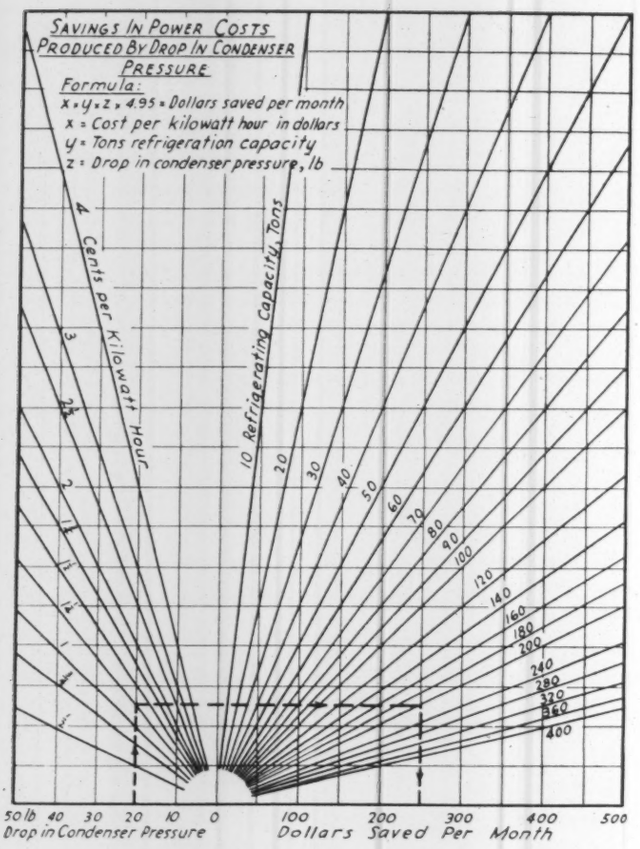
**Note—This total yearly cost also does not include the cost, maintenance or operation of any evaporator equipment or auxiliaries which might add some 25 per cent, but is here given simply for the purpose of comparison.

In comparing Tables 2 and 3, it is interesting to note that whereas the contemplated saving in using a small suction pipe main was some $200, instead of a saving being afforded there was an additional capital investment required of $3,300 to correct the error. The worst offense is that whereas the yearly operating costs might have been $25,892.50 with the correct size suction pipe main, they were $30,159.00—most of which is added power cost. This additional operating cost is roughly 16 per cent, which is greater than the net profit in many a business enterprise and is a loss that is bound to prevail year after year until the defect is remedied.

Discharge Piping

It is equally essential that the discharge piping of a refrigerating system be properly designed, for here again it is possible for poor judgment or indiscretion to cause an abnormal pressure drop that will affect the operation of the system adversely. The condenser has probably been designed and engineered properly for the capacity of the compressors and the low side of the plant and has the right duty or performance in view of the quantity and temperature of the condenser water available. However, if the plant layout is such that a long irregular discharge line is required having a number of elbows, bends or offsets, it is quite possible to choose too small a pipe size, thus causing a considerable pressure drop in the line—which simply adds to the compressor burden. In case the discharge pipe line is ample for the refrigeration load and the length and arrangement of the pipe main so that the vapor velocity is within prescribed limits and the pressure drop is small enough to be negligible, the compressor discharge pressure will be the same as the condensing pressure. But, if there is a considerable pressure drop through the discharge line due to excessive velocity and friction in the pipe, the discharge pressure against which the compressors must operate is the sum of the condensing pressure and this pressure drop. Obviously, little can be done to lower the condensing pressure if the condenser is of the proper capacity, clean and free of foul gases, for this pressure is principally determined by the quantity and temperature of the condensing water. However, it is possible to obtain a low practical pressure drop in the discharge main when the plant is installed so that the sum of these two factors will be a practical minimium. Table 4 shows a comparison in which the compressors and the low side are the same in size and capacity but the discharge pressure in one case is 145.3 lb and in the other case is 165.3 lb per sq in. gage.

It is apparent from Table 4 that the increase in compressor discharge pressure has required slightly more displacement per minute per ton and at the same time the net compressor displacement has been diminished for the volumetric efficiency of the machines is less, resulting in a reduction in compressor capacity of 5.3 tons or over 3 per cent. At the same time, the total indicated horsepower has increased from 129.6 to 136.8, which is an increase of about 5.6 per cent all of which is obviously detrimental to good operating efficiency. These comparisons are, of course, purely hypothetical and are given to draw attention to the magnitude of losses under these conditions. The pressure drops may be a little large to emphasize the points in question and yet they



are not far from some actual conditions met in the field.

The compressor discharge pressure is affected not only by the pressure drop in the discharge line, but by the amount of foul gases, quantity and temperature of condensing water, the water velocity over the condensing surface, the condition of these surfaces and the capacity of the condenser. For this reason, any change or improvement in any of these factors that will tend to reduce the compressor discharge pressure will improve the operating economy by reducing the total amount of power required for operating the compressors very greatly and at the same time, will increase the tonnage capacity of the whole system.

The chart indicates the saving in power costs produced by a drop in ammonia compressor discharge pressures in electric driven equipment and, of course, these savings are proportional in compressors driven by other prime movers than electric motors. For example, if we consider a 200 ton plant in which the compressor discharge pressure is high and we are able to reduce this pressure 20 lb, and the average power cost is 1¼ cents per kwhr, the chart shows that the saving in power bills amounts to $250 per month. This is a considerable amount when we remember that these savings are accumulative, month after month, and should demand the serious attention of the owner or his operating personnel.

There are many instances of industrial refrigeration plants that have been installed with items of equipment of suitable capacity in which the piping has been poorly designed with little or no thought or attention given to limits on liquid and gas velocities. In some instances, the errors were so large that the plants failed to meet capacity guarantees and changes had to be made to rectify their troubles. In many others, the losses are not realized and the plants are still running in spite of them because the profits are large enough to hide them.

Through the benefit of experience, cooperation between various individual engineers and companies, scientific investigation and technical research, considerable engineering data have been prepared and published regarding the limits of liquid and gas velocities for the various commonly used refrigerants so that pressure drops in suction and discharge piping mains can be reduced to a practical minimum. Regardless of the size of a refrigerating plant, piping connections involving assets or liabilities will always exist. In many cases, the total cost of the piping represents less than 10 per cent of the cost of the equipment it serves. It is, therefore, foolish economy to jeopardize the efficient operation of any commercial or industrial refrigerating system by using guesswork or "rule-of-thumb" methods, for the gamble is not worth the saving even if it succeeds.

Table 4—Comparative Data with Different Discharge Pressures

	At Comp. Dis. Press. of 145.3 Lb	At Comp. Dis. Press. of 165.3 Lb
Evaporator pressure, lb per sq in.	26.0	26.0
Suction line pressure drop, lb per sq in.	0.7	0.7
Compressor suction pressure, lb per sq in.	25.3	25.3
Ammonia condensing pressure, lb per sq in.	145.3	145.3
Discharge line pressure drop, lb per sq in.	0	20
Compressor discharge pressure, lb per sq in.	145.3	165.3
Refrigerating effect, Btu per lb.	480.6	472.1
Weight of ammonia per min per ton, lb.	0.4163	0.4236
Specific volume of suction vapor, cu ft per lb.	7.047	7.047
Displacement required per min per ton, cu in.	5068	5158
Compressor compression ratio	4.00	4.50
Volumetric efficiency, per cent	76.3	75.0
Compressor displacement, gross, cu in per min	1,000,000	1,000,000
Compressor displacement, net cu in. per min.	763,000	750,000
Compressor capacity, tons refrigeration	150.7	145.4
Indicated horsepower per ton	0.860	0.941
Indicated horsepower, total	129.6	136.8

Dust Studies Simplified by Glycerine

With the potential menace of industrial dusts to health and property generally recognized as a definite danger, there is increasing interest in dust counts as the first step in the elimination or minimization of this hazard. A simple method for making these studies consists of exposing glass slides smeared with glycerine gelatine, according to the Glycerine Producers' Association.

The dust particles deposited on the film in a given time at varying distances from the source of the air pollution can readily be counted under a microscope. The glycerine-gelatine jelly can be made as follows:

Glycerine	3½ oz
Gelatine	½ oz
Water	3 oz
Phenol	1 dr

Dissolve the gelatine in the water and when completely dissolved, add the glycerine and the phenol. Warm for 15 minutes with constant stirring. (Do not allow the temperature to rise over 75 C). When cooled and solidified, drain off the excess water. Store the jelly in a cool place in an air-tight container. This jelly may also be used for mounting microscopic specimens.

Correcting Defective Heating Systems

By O. E. Stossel*

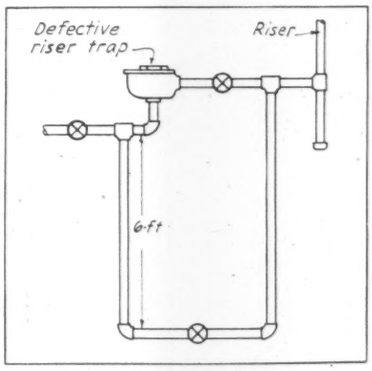
IT IS usually true that it pays to spend the money necessary to put a heating system into proper condition for its best operation, for an obsolete or incorrectly installed system represents a continual waste and gives poor service. Sometimes, however, the money for the needed work just isn't available, and the operator must do the best he can with what he has. In the case of the two hotels discussed here, lack of funds made thorough overhauling of the vacuum heating systems impossible. Therefore, something had to be done with the limited means available.

The heating plant of a 400 room hotel was defective in several respects. With both vacuum pumps running, it was impossible to get any vacuum because of numerous leaks. Most radiator and all riser traps were passing steam. Distribution of heat was most uneven.

Fortunately the leaks could be stopped quickly. Unions, check valves in the vacuum pump, valve stems, and the relief valve to the atmosphere proved to be the offenders. Bad leaks, such as cracked fittings and pipes, were indicated by the temperature of the radiators which became progressively colder toward the leaks. As a last resort, enough steam pressure was put on the line to show up the remaining leaks, although this damaged some ceilings and walls.

Leaking Traps

Neither time nor money were available for checking and replacing radiator traps, although an expenditure for the work would have been a wise investment. Therefore, it was necessary to operate in such a way that the least amount of steam would be lost through the leaking traps. On account of the ample radiation surface per room, the radiators could be kept only partly filled in any but severe weather, which was accomplished by adjusting the firing rate of the oil burner. The system has no reducing valve and the boilers operate under a vacuum at all times. All riser traps, of course, had to be replaced in order to get any results. In a few cases they were replaced by a "pipe trap" which was made deep enough to hold the condensate against the pressure differential (see sketch). The low temperature of the return condensate indicated small losses through the radiator traps. Only when the full radiation surface was needed in order to heat the rooms did the temperature of the condensate rise unduly high. In this case the vacuum would drop below 5 in., and uneven distribution of heat became noticeable. At other times a high vacuum was maintained and the increased volume of the steam created a sufficiently uniform distribution. The improvement in service and the savings in fuel were very satisfactory after these changes had been made.



Pipe trap used on risers

A 600 room hotel with 38,000 sq ft of radiation was very difficult to heat. Radiator traps and riser traps were in poor condition. The riser traps were replaced by combination float and thermostatic type traps. Radiator traps were tested and replaced wherever necessary. The testing was done on an open steam and water tap. This is not quite accurate, as it does not represent the true working conditions of the traps, but the method was convenient and probably satisfactory for the situation.

Pockets in Piping

There were—and still are—many pockets in the steam and return lines. Due to details in the construction of the building they can be eliminated only very slowly. In spite of these line pockets, however, it is possible to heat with a low pressure differential without getting uneven heat distribution.

On account of these line pockets and the length of the horizontal feed lines, it was at times impossible to get any circulation at all. Large amounts of hot condensation would collect in the feed lines and discharge through the riser traps into the vacuum pump. This caused the pressure differential to be lowered and the steam to bypass most radiators. High temperatures of the return condensate and a drop in the steam load indicated this condition. Only after the lines had been cleared of excess condensation could normal operation be resumed.

It was evident that the line pockets would not be as offensive, and that normal circulation could be maintained, if this excess condensation were prevented. The condensation was caused by poor insulation of the feed lines and by the poor quality of the steam. Nothing could be done about the insulation; it was therefore necessary to improve the quality of the steam. This was accomplished by reducing the steam enough to get the necessary superheat for re-evaporation of a part of the condensate in the feed lines. A high vacuum was carried from the reducing valve on. The pilot line on the diaphragm of the reducing valve had to be connected farther out on the secondary side of the main line in order to get more lifting power. Weight was also added to the closing side of the valve lever.

One of the vacuum pumps at times would lose its suction and idle while the other one took over the load. This happened especially under a high vacuum during low load periods, and the idling pump would heat up very quickly. A small priming pipe from the water discharge line to the suction chamber of the pump corrected this condition. This plant is now working on a very small pressure differential and without water hammer noises. The low temperature of the return condensate indicates fairly efficient operation.

*Progressive Hotels, Inc. (hotel management).

From a Field Engineer's Notebook

[Methods of supporting piping under various conditions that can't always be foreseen in time for the plans and must be determined after inspection of the situation in the field]

By **Allen M. Perry***

IN PLANNING construction or modernization of industrial and power plants, it is frequently impossible to indicate how all of the piping shall be supported due to various interferences which may arise. Frequently the type of supports must be determined by field engineers after inspecting the conditions.

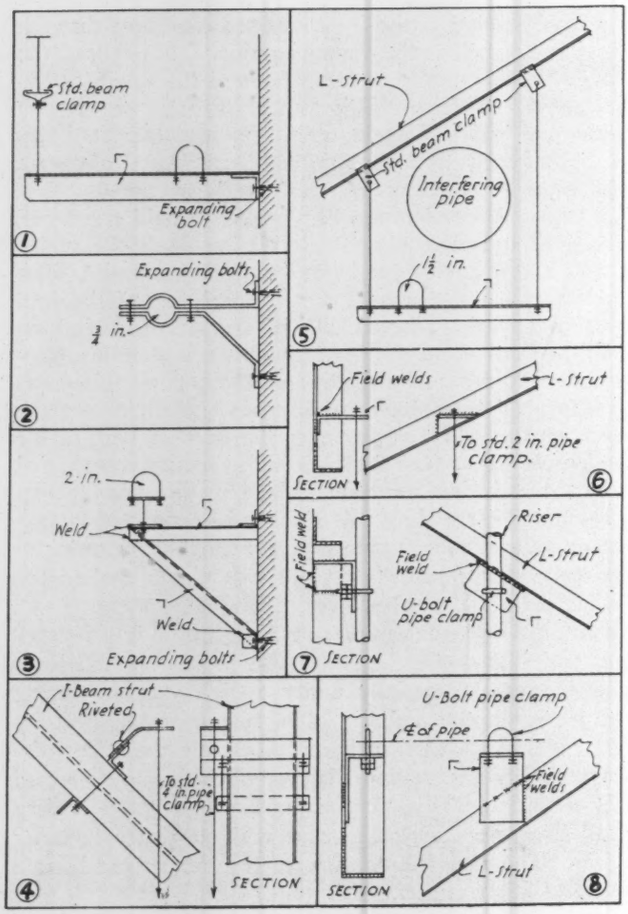
The accompanying sketches, which have been taken from field notebooks and drawings, indicate various ways in which different conditions were handled on a large modernization project. Their value is chiefly to expedite special designs that must be fabricated quickly in the field. Examination will indicate that standard beam and pipe clamps fit into many of them, and that simple combinations of structural shapes and the use of welding expedite construction and installation.

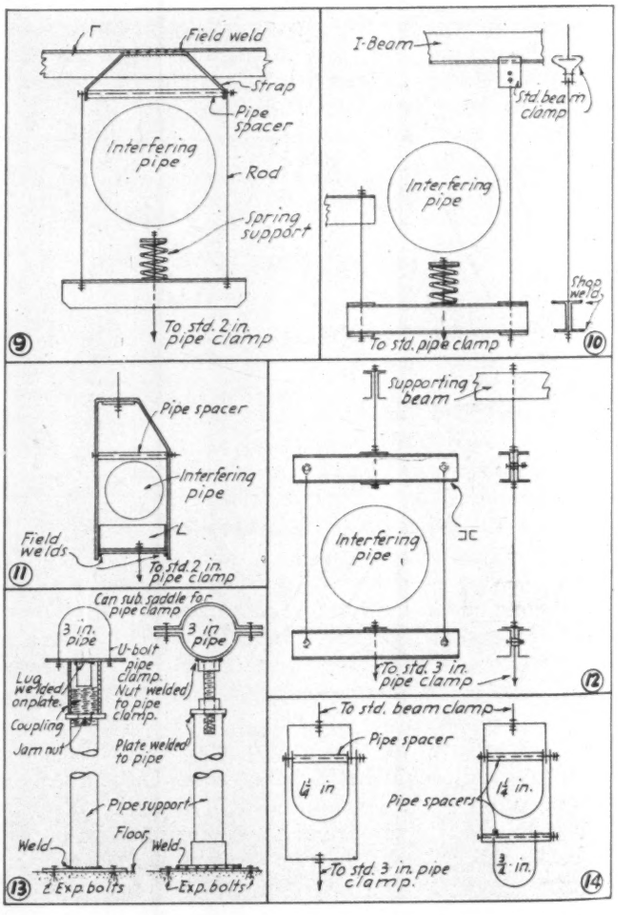
Forty-one other sketches were published in the December and January issues.

*Formerly with M. H. Treadwell Co., General Contractor.

Key to Finding Pipe Support for Various Conditions

Condition	Sketch Numbers: Horizontal Runs	Risers
Near wall	1-2-3	....
Near beam or platform	9-10-11-12-14	....
Above floor	13	....
Near strut	4-5-6-8	7
Interference above	5-9-10-11-12-14	....
Several pipes in different planes	14	....
Spring support or adjustment for position	3-9-10-13	....





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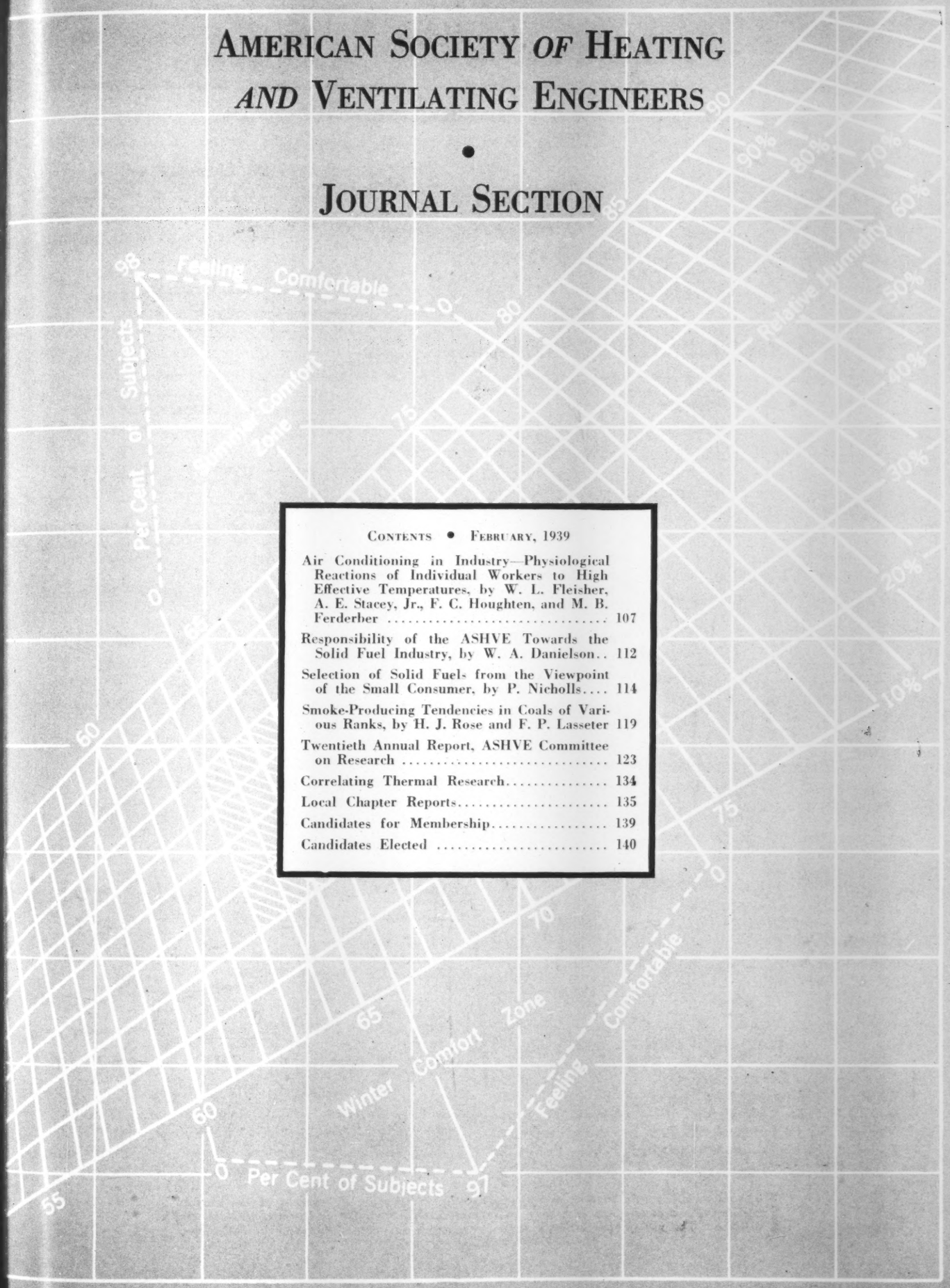

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Research Activities at Pittsburgh

Completing a year of definite progress and accomplishment, the Committee on Research met in Pittsburgh during the week of January 23 to review present research investigations and plan future objectives. In addition to the two general meetings of the Committee on Research, which were held on Sunday and Wednesday, several Research Technical Advisory Committees met to discuss plans of procedure for the current year.

At the opening technical session held Monday afternoon, special recognition was given to the 20th anniversary of the establishment of the Research Laboratory of the Society. Past chairmen of the Committee on Research who were present included G. W. Barr, J. I. Lyle, W. H. Driscoll, Thornton Lewis, H. P. Gant, F. B. Rowley, C. V. Haynes, G. L. Larson, John Howatt, A. P. Kratz and W. A. Danielson. Two Laboratory papers were presented at this session dealing with Frictional Resistance to the Flow of Air in Straight Ducts and Air Conditioning in Industry. Several of the other technical sessions were devoted to subjects which included papers contributed by cooperative institutions and reports of Technical Advisory Committees.

At the Committee meeting of the group on Air Conditioning Requirements of Glass Sunday afternoon, it was indicated that tentative standards had been proposed for testing the heat transmission of glass block wall construction, as well as a uniform method for determining overall coefficients for single and double glazing. Preliminary plans were outlined for conducting research which will lead towards the development of a method for determining the solar heat transfer through glass blocks and various window arrangements.

Announcement was made at the committee meeting on Radiation and Comfort Winter and Summer and Effect of Varying Humidity on Radiant Heating and Cooling that sufficient funds had been contributed to erect two test rooms at the Laboratory in Pittsburgh where studies on the effect of radiation on the feeling of comfort would be investigated. The committee approved the general construction of the rooms and outlined a recommended procedure for conducting the work.

At the organization meeting of the 1939 Committee on Research it was announced that the present chairman and vice-chairman were persuaded to continue their respective positions for another year and C.-E. A. Winslow was appointed to serve as technical adviser to the group. Members of the Executive Committee appointed for the current year were W. L. Fleisher, chairman; J. H. Walker, vice-chairman; A. E. Stacey, Jr., T. H. Urdahl, and J. H. Van Alsburg. To collect the necessary funds for carrying on general and earmarked research, Mr. Walker was appointed to serve as the chairman of the Finance Committee with additional personnel to be announced later. New cooperative contracts were authorized for research work to be investigated at the University of Pennsylvania on psychrometry and Massachusetts Institute of Technology on sound control. Approval was given to the appointment of a Committee on Instruments which will function to establish methods of standardization and indicate the range of usefulness for each type of apparatus. Elsewhere in this JOURNAL appears the Twentieth Annual Report of the Committee, which outlines in detail the activities of the several technical advisory groups. The executive committee felt that the energetic work accomplished by the committees this year warranted little alteration, but in the March JOURNAL will be announced the few changes of committee personnel that were thought desirable to extend the activities of research during the year 1939.

May I take this opportunity to express my personal appreciation for the assistance of all those who have contributed to the progress of research for the Society in 1938. Also to the manufacturers, companies, and associations, who have contributed support to the research fund of the Committee, may I pay special tribute for making possible research investigations which might not have been otherwise possible.

WALTER L. FLEISHER, *Chairman*,
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NORTHERN OHIO: *Organized,* 1916. *Headquarters,* Cleveland, O. *Meets,* Second Monday in Month. *President,* J. P. JONES, 448 Terminal Tower. *Secretary,* C. M. H. KAERCHER, 3030 Euclid Ave.

OKLAHOMA: *Organized,* 1935. *Headquarters,* Oklahoma City, Okla. *Meets,* Second Monday. *President,* E. W. GRAY, Box 1498. *Secretary,* A. A. HOPPE, 1941 Northwest 17th St.

ONTARIO: *Organized,* 1922. *Headquarters,* Toronto, Ont. *Meets,* First Monday in Month. *President,* H. B. JENNEY, Royce and Lansdowne Aves. *Secretary,* H. R. ROTH, 57 Bloor St., W.

PACIFIC NORTHWEST: *Organized,* 1928. *Headquarters,* Seattle, Wash. *Meets,* Second Tuesday in Month. *President,* C. W. MAY, 1201 Smith Tower. *Secretary,* R. D. MORSE, 1534 First Ave. S.

PHILADELPHIA: *Organized,* 1916. *Headquarters,* Philadelphia, Pa. *Meets,* Second Thursday in Month. *President,* H. H. ERICKSON, 1124 Spring Garden St. *Secretary,* H. H. MATHER, 1000 Chestnut St.

PITTSBURGH: *Organized,* 1919. *Headquarters,* Pittsburgh, Pa. *Meets,* Second Monday in Month. *President,* R. A. MILLER, 2200 Grant Bldg. *Secretary,* T. F. ROCKWELL, Carnegie Inst. Tech.

ST. LOUIS: *Organized,* 1918. *Headquarters,* St. Louis, Mo. *Meets,* First Tuesday in Month. *President,* E. E. CARLSON, 1010 Louderman Bldg. *Secretary,* D. J. FAGIN, 1017 Olive St.

SOUTHERN CALIFORNIA: *Organized,* 1930. *Headquarters,* Los Angeles, Calif. *Meets,* Second Tuesday in Month. *President,* H. M. HENDRICKSON, 5051 Santa Fe Ave. *Secretary,* A. J. HESS, 2616 West 70th St.

NORTH TEXAS: *Organized,* 1938. *Headquarters,* Dallas, Tex. *Meets,* Second Monday in Month. *President,* C. L. Kribs, Jr., 4209 Shenandoah Ave., Dallas, Tex. *Secretary,* L. S. Gilbert, 1314 Liberty Bank Bldg., Dallas, Tex.

SOUTH TEXAS: *Organized,* 1938. *Headquarters,* College Station, Texas. *President,* R. F. Taylor, 911 Bankers Mortgage Bldg., Houston, Tex. *Secretary,* W. H. Badgett, Texas Engrg. Experiment Station, College Station, Tex.

WASHINGTON, D. C.: *Organized,* 1935. *Headquarters,* Washington, D. C. *Meets,* Second Wednesday in Month. *President,* S. P. EAGLETON, 3522 "S" St., N. W. *Secretary,* E. V. FINERAN, 411 Tenth St., N. W.

WISCONSIN: *Organized,* 1922. *Headquarters,* Milwaukee, Wis. *Meets,* Third Monday in Month. *President,* D. W. NELSON, University of Wisconsin, Madison, Wis. *Secretary,* T. M. HUGHEY, 906 N. Fourth St.

Pittsburgh Experiment Station of the U. S. Bureau of Mines where the Research Laboratory of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS is located

Air Conditioning in Industry

Physiological Reactions of Individual Workers to High Effective Temperatures

By W. L. Fleisher,* A. E. Stacey, Jr.,**, F. C. Houghten,*** and M. B. Ferderber, M.D.†, (*MEMBERS*)

(Part 1)

THE work of the ASHVE Research Laboratory during the past summer was limited to a study of the physiological reactions of men while carrying on light work in atmospheric conditions including effective temperatures from 77 to 92 deg, with relative humidities of 60, 75 and 90 per cent. The investigations were conducted in the psychrometric chambers of the Laboratory located in the Bureau of Mines Building in Pittsburgh, under the following Technical Advisory Committee on Air Conditioning in Industry: A. E. Stacey, Jr., *Chairman;* Philip Drinker, Dr. Leonard Greenburg, H. P. Greenwald, A. M. Kinney, J. W. Kreuttner, L. L. Lewis, Dr. W. J. McConnell, Dr. C. P. McCord, P. A. McKittrick, and Dr. R. R. Sayers.

Introduction

It is well in beginning a paper of this nature to outline briefly the history of previous investigations and list the several factors which are generic to the subject. Eleven basic points are enumerated herewith which have an important relationship to proper air conditioning in industry.

1. The simultaneous relationship of temperature and humidity to the reactions of human beings *at work.*
2. The air conditions required for the making of goods, and the air conditions encountered in the extraction of basic materials.
3. The change in the required atmospheric conditions with changes in the manpower output.
4. The increased amount of work healthfully obtained with better conditions.
5. The problem of dust, vapors, fumes and gases which may be harmful to workers.
6. The development of bacteria, spores, etc., that may produce unsanitary conditions or be harmful to processes.
7. The prevalence of odors arising from working conditions.
8. The prevalence of noise disturbances.
9. Legislation required to protect labor and capital.
10. The engineering basis on which the requirements called for by legislation or determined by research can be calculated.
11. Analysis of research already done or being done or that research required to be done on which to base sound conclusions.

Underground mining, which eventually brought about research covering the requirement of human beings for proper air conditions in industry, was for thousands of

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years the most discredited of all industrial work. A freeman would not work underground in close and confined spaces, so the laborious, dark, wet and dangerous work of extracting minerals from underground was allotted to slaves, criminals and children. Due to lack of tools and technology, the difficulty of piercing the earth to explore and exploit the veins was so exhausting, that only the smallest amount of materials was removed. Children of from six to twelve years of age dragged sacks weighing as much as 45 lb through minute passages for hours at a time. Coal and tin, copper and gold and silver were the prizes. If it were not for the fact that the world at present is suffering from a retrogression of humanitarian ideas, approaching a general undermining of all the progress achieved in 2500 years, one might dwell longer on the industrial use of children in the production of wealth.

Early mines uncovered in archeological searches have disclosed the skeletons of hundreds of workers who undoubtedly died from the heat and dampness, combined with the efforts that they were compelled to exert. It is obvious that under such callous conditions, no thought was given to the health and safety of the worker.

Egyptian, Phoenician, Cretan, Greek, Roman and Spanish records all depict deep mining from at least 5000 B. C. Progressing down to present times and particularly in the light of recent exploitation of deep mine ventilation in South Africa, the following quotation from the 11th Edition of *Encyclopaedia Britannica*, published in 1910, Vol. XVIII, under Deep Mining is pertinent:

"The deepest mine in the world is the No. 3 shaft of the Tamarach Mine in Houghton County, Michigan, which has reached a vertical depth of about 5200 feet.....

In the Transvaal gold region (South Africa), a number of shafts have been sunk to strike the reef at about 4000 feet. In most cases the deposits worked are known to extend to much greater depths than have been reached. The possibility of pumping and hoisting from great depths has been discussed, and it remains now to consider the other conditions which will tend to limit other mining operations in depth; namely, increase of temperature and increase of rock pressure. Observations in different parts of the world have shown that the increase of temperature in depth varies, in most localities the rise being at the rate of 1 deg for 50 to 100 feet of depth, while in the deep mines of Michigan and the Rand an increase as low as 1 deg for each 200 feet has been observed. In the Comstock Mines at Virginia City, Nevada, it is possible to continue mining operation at rock temperatures of 130 degrees. In these mines a constant supply of pure air, about 1000 cubic feet per minute, was blown into the hot working places through light iron pipes. The air issuing from these pipes was dry and warm and served to keep the temperature of the air below 120 degrees, at which temperature it was possible for men to work continuously for ½ hour at a time and for 4 hours in a day. In some places work was conducted with rock temperatures as high as 150 deg F with air 135 deg. In these very hot drifts the fatality was large. In the Alpine tunnels, where the air was *moist* and probably not as pure as in the Comstock Mines, great difficulties were experienced in prosecuting the work at temperature of 90 deg F or less. The mortality was large and it was believed by the engineers that temperatures over 104 deg would have proved fatal to most of the workmen. Deep mines, however, are generally dry so that in most cases it will be possible to realize the more favorable conditions of the Comstock Mines. Assuming an initial mean temperature of 50 deg F and increments of 1 deg for 100 and for 200 feet, a rock temperature of 130 deg will be reached at 8,000 to 16,000 feet."

This quotation is reproduced in order to give evidence that the rise in temperature with depth of mine was early understood and resultant conditions for greater depths prophesied, even though the depths mentioned had not then been reached. It is also evident from this statement that moisture added to the sensible heat was understood to have a deleterious effect on the physiological reactions of workers.

Deep mining has been used as an illustration because it existed long before machine-operated industrial activity was prevalent. In fact, the establishment of the ASHVE Research Laboratory at Pittsburgh revolves about the interest of the U. S. Bureau of Mines in the health and working conditions of labor in mining.

The history of the legislation and investigation of ventilation, particularly in coal mines, dates back only about a hundred years. In England, an investigation of the reasons for explosions in coal mines was started in 1835 by an Act of Parliament, when a committee was appointed to investigate "lamentable catastrophes which have occurred in the mines of Great Britain, with the view of ascertaining and suggesting means for preventing the recurrence of similar fatal accidents." The committee reported to Parliament, but no laws were enacted although the investigation brought out facts and recommendations.

In 1843 a law making the inspection of mines a state function was passed by Parliament. This appears to be the first law, either in the United States or England, where state regulation of mining was enacted. Subsequently great interest was taken in solving the ventilation problems in Great Britain. Although certain methods were recommended the mine owners neglected to apply the suggested methods because of lacking compulsory requirements, until a continuous list of disasters brought about a new Act of Parliament in 1850, placing all coal mines under state inspection.

The United States was slower in considering this question, and although the miners petitioned the Pennsylvania Legislature in 1858 for the same type of laws as those governing the mines in Great Britain, no action was taken on their petition until an explosion in 1869 at Avondale, Pennsylvania, forcibly brought the matter of mine ventilation to the attention of the public. This disaster was responsible for an Act of the Pennsylvania Legislature, in 1870, which stated:

"In a non-gaseous mine, the minimum quantity of air shall not be less than 150 cubic feet per minute for each person employed. In a mine wherein explosive gas is being generated . . . the minimum quantity of air shall not be less than 200 cubic feet of air per minute for each person employed therein, and as much more in either case as one or more of the inspectors may deem requisite."

The historical background of ventilation in mining has been developed so that a differentiation may be given between present research activities and those researches that had to do with the conditions existing in mines. It was obvious for centuries that something had to be done in the deep, dark holes in which mining was conducted and in which either explosive gases or dusts were so prevalent. However, it was really the requirements of such industries as the textile industries which prompted the present investigations. It has become evident by gradual education that the power required to manufac-

ture products at high speeds, such as are now existent in the textile plants, has created enormous amounts of heat by friction and that all of the power developed in industrial plants is translated into sensible heat. It is only within the last few years that engineers have realized the effect of radiant heat as producing a high resultant total heat in an enclosure. Still later it has been realized that the energy output of human beings is translated into both sensible and latent heat, which is added to these other factors, and that all of these items are cumulative. It has been further shown that hygroscopic material functions at a definite relative humidity which is independent, to a great extent, of the dry-bulb temperature. As the temperature from the sources mentioned rises inside an enclosure in which hygroscopic material is being developed and manufactured, more and more moisture must be added to the air in order to maintain a constant relative humidity. A decrease in the relative humidity produces, on high speed machines working with dielectric materials, static electricity which makes the operation of the machines and the production of properly finished goods difficult unless the relative humidity is maintained at the proper desirable high levels. All of these factors combined tend to create conditions affecting the physiological reactions of the workers. None of the former investigations visualized the correlation of these different factors, and it is felt that although the basic ideas have been more or less prophesied to a great extent, they have been definitely overlooked and neglected, notwithstanding their great importance to both labor and capital.

No excuse is being offered for the research that has been undertaken, but it is important to bring to the attention of the public the great necessity for this correlated research as the beginning of specific research in many different industries. In order to present some of the work that has been accomplished certain facts are given which influenced the methods of investigation.

Over a period of many years research has been directed in an effort to determine a zone of comfort. In this research it was discovered that within certain wide limits, the individual experienced equal comfort at widely different points on the dry-bulb scale with different wet-bulb or relative humidity relationships as illustrated in Fig. 1. In summer equal comfort was experienced by large groups with maintained conditions of 76 F dry-bulb and 75 per cent relative humidity, and 78 F dry-bulb and 50 per cent relative humidity, and 82 F dry-bulb and 30 per cent relative humidity. All of these results were obtained with air velocities of 15 to 25 fpm. The line drawn through these points was designated as an effective temperature line and designated by the temperature of saturation intersected by the line or curve through these three points as a 73 deg ET line.

These investigations covering a period of 15 years are still being conducted with astonishingly accurate results, although many questionable points are still to be determined. Practically all of these investigations have been, at least lately, concerned with cooling—with people at rest—and with the questions of shock, drafts, removal of perspiration and the cycle of sensations: cold, warm, hot, comfortable. The object of the present research is undertaken to proceed deeper and further than comfort research, because no attempts are being made to indicate the results by physical reactions, or sensations, but primarily to secure the basic physiological data.

Similar investigations in this field were begun about 1860. In the report of the New York State Commission on Ventilation, a very comprehensive historical account of the investigations of earlier medical workers is given in a most interesting review. A few of the points from that account are presented herewith to indicate a distinct trend towards the investigations referred to in this discussion. Cardinal Polynac, in 1713, stated that inequalities of temperature and want of ventilation were responsible for numerous maladies. In 1883, F. T. F. Hennans, in *Archives für Hygiene*, discussed the strong probabilities that the influences exerted by the air of a badly ventilated room were thermal. He gave credit for this theory to Pettenkover. It was only in 1905 that Flügge established the thermal theory of ventilation on a fine basis. From that time on J. S. Haldane and his associates very definitely enunciated the theory of the

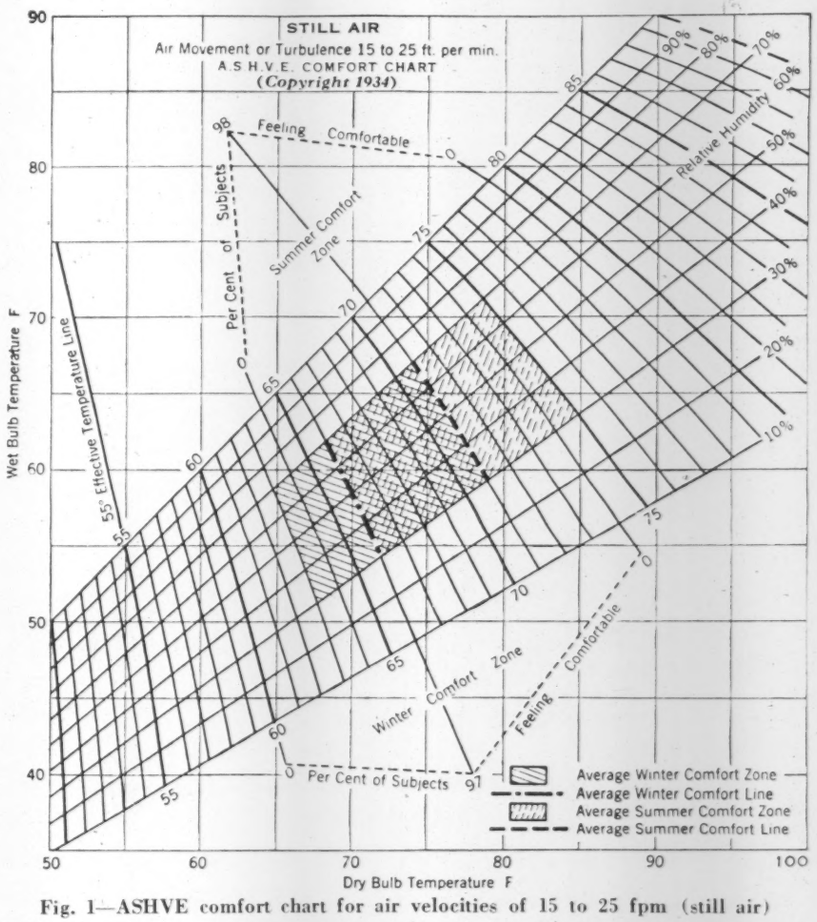

Fig. 1—ASHVE comfort chart for air velocities of 15 to 25 fpm (still air)

Note.—Both summer and winter comfort zones apply to inhabitants of the United States only. Application of winter comfort line is further limited to rooms heated by central station systems of the convection type. The line does not apply to rooms heated by radiant methods. Application of summer comfort line is limited to homes, offices and the like, where the occupants become fully adapted to the artificial air conditions. The line does not apply to theaters, department stores, and the like where the exposure is less than 3 hours.

deleterious effects of high temperatures, combined with high wet-bulbs. A paragraph is quoted from the Ventilation Commission Report, which bears directly on this subject:

"Evidence in favor of the views advanced by Flügge and his associates accumulated rapidly during the immediately succeeding years, particularly in England. Striking evidence in regard to the effect of high temperature combined with high humidity had been obtained by Haldane, Pembrey, Boycott and Hill in the course of studies on problems of industrial hygiene. In the year that Flügge's researches were published Haldane reported that the rectal body temperature begins to rise when the wet bulb temperature of the air reaches 34.4 degrees C. (93 F.) if the subject be at rest in moving air, and that the same condition appears at 31 deg. C. (88 F.) wet bulb if the subject be at rest in still air, at 30½ deg. C. (88 F.) wet bulb when exercising in moving air and at 25½ deg. C. (78 F.) when exercising in still air. A marked increase in pulse rate accompanied by throbbing in the head, dysnia and a general feeling of exhaustion and discomfort accompany the rise in rectal temperature."

Hill, Flack, MacIntosh, Rollins and Walker, writing of *The Influence of the Atmosphere to Our Health and Comfort in Confined and Crowded Spaces (Smithsonian Miscellaneous Collections,* Vol. 60, No. 23, Publication 2170) reported:

"In one class of experiments we shut within the chamber seven or eight students for about a half an hour and observed the effect of the combined atmosphere upon them. . . . The wet bulb temperature rose meanwhile to about 26.6 to 29½ C. (80 to 85 F.) and the dry bulb a degree or two higher. The students went on chatting and laughing but bye and bye as the temperature rose they ceased to talk and their faces became flushed and moist. . . . Their discomfort was relieved to an astonishing extent by putting on the electric fans placed on the roof."

The investigations of the New York State Commission, initiated in 1913, covered almost every phase of human reaction to temperature and humidities and the consequent wet-bulbs, within the average ranges likely to be experienced in school-houses, from the most favorable to the worst conditions, correlating these conditions with different physical and mental endeavors which might be exerted by the students.

Society research, undertaken at the Laboratory in Pittsburgh, starting in 1920, indicated that the upper limit of the effective temperature to which the human organism is capable of adapting itself without serious discomfort or injury to health is 90 deg ET for men at rest and between 80 and 90 deg ET for men at work, depending upon the rate of work. An effective temperature of 85 deg may mean 87 F dry-bulb and 84 F wet-bulb or 100 F dry-bulb and 76 F wet-bulb; the first giving a relative humidity of 90 per cent and the second a relative humidity of 33 per cent. Or this same relationship might represent a dry-bulb temperature of 114 F and a wet-bulb of 65 F and about 3 per cent relative humidity, all of which may be referred to in Fig. 2.

In 1923 the Research Laboratory conducted a series of tests[1, a] which indicated that the wet-bulb temperatures above 85 F seriously upset the physiological conditions of the subjects, as shown by rise in rectal temperature, pulse rate and blood count, but with no serious change in the metabolism of the subjects. In the summary the authors state:

"1. There is an inability of the body at rest and in still air to compensate for saturated atmospheric conditions exceeding 90 F.

2. The physiological effects resulting from exposure to high temperatures and humidities depend upon both the wet- and dry-bulb readings.

3. The exhaustion and weakness following subjection of human beings to a very high temperature and humidity for a short period is not so severe as subjection to a moderately high temperature and humidity, but for a longer period.

4. The highest dry-and wet-bulb temperatures attained and length of time endured in the experiments are as follows:

Dry-Bulb Temp, F	Wet-Bulb Temp, F	Relative Humidity Per Cent	Time, Minutes
112.5	112.5	100	35
120.2	104.02	60	40
147	108.4	30	45
157	100.43	15	45

5. The pulse-rate, rather than the rise in body temperature, apparently determines the extent of the discomfort experienced by the subject. Subjects became very uncomfortable after the pulse-rate exceeded 135 pulsations per min, and complained of unbearable and distressing symptoms when the pulse exceeded 160 per min. The highest pulse rate recorded was 184 per min.

6. The systolic and diastolic blood pressure fell with moderate increase in temperature and humidity, and the systolic rose and the diastolic fell, thus increasing the pulse pressure, in high temperatures and humidities."

The reason for quoting this summary is to indicate the limits which the early tests covered. The purpose in re-establishing this most essential research was to simulate actual working conditions for a group of people, that would approach, from the standpoint of bearable effective temperatures, what might be expected, or that should be produced, so that men and women, without injury, could work for the periods of time essential in such industrial establishments under the most favorable conditions that could be economically produced. Also to determine from a sufficiently large group, the variations in the physiology of different subjects so that a method of determining those possible divergences in human beings may be established for the selection of a worker in a particular industry.

With the movement of the textile industry from New England and Pennsylvania to the south and the increasing demands of labor for better and more healthful conditions, legislation was proposed in various states to protect the worker. Practically all legislation called for *proper ventilation.* It was with the idea of interpreting for the world this indefinite expression concerning proper ventilation that this work was begun based on already accomplished but incomplete research, which has previously been quoted in a meager summary. It was not only the purpose of this research to determine, if possible, at what point in conditions which may readily occur in industry a physiological break takes place in the workman, but also to outline from an engineering standpoint what methods may be pursued, from an air conditioning angle, to relieve or prevent the occurrence of critical conditions.

In the textile field, particularly in the south, the average mill building, unless properly ventilated and treated either by cooled air or large volumes of circulated air,

[a] Reference numbers refer to listing of papers in bibliography.

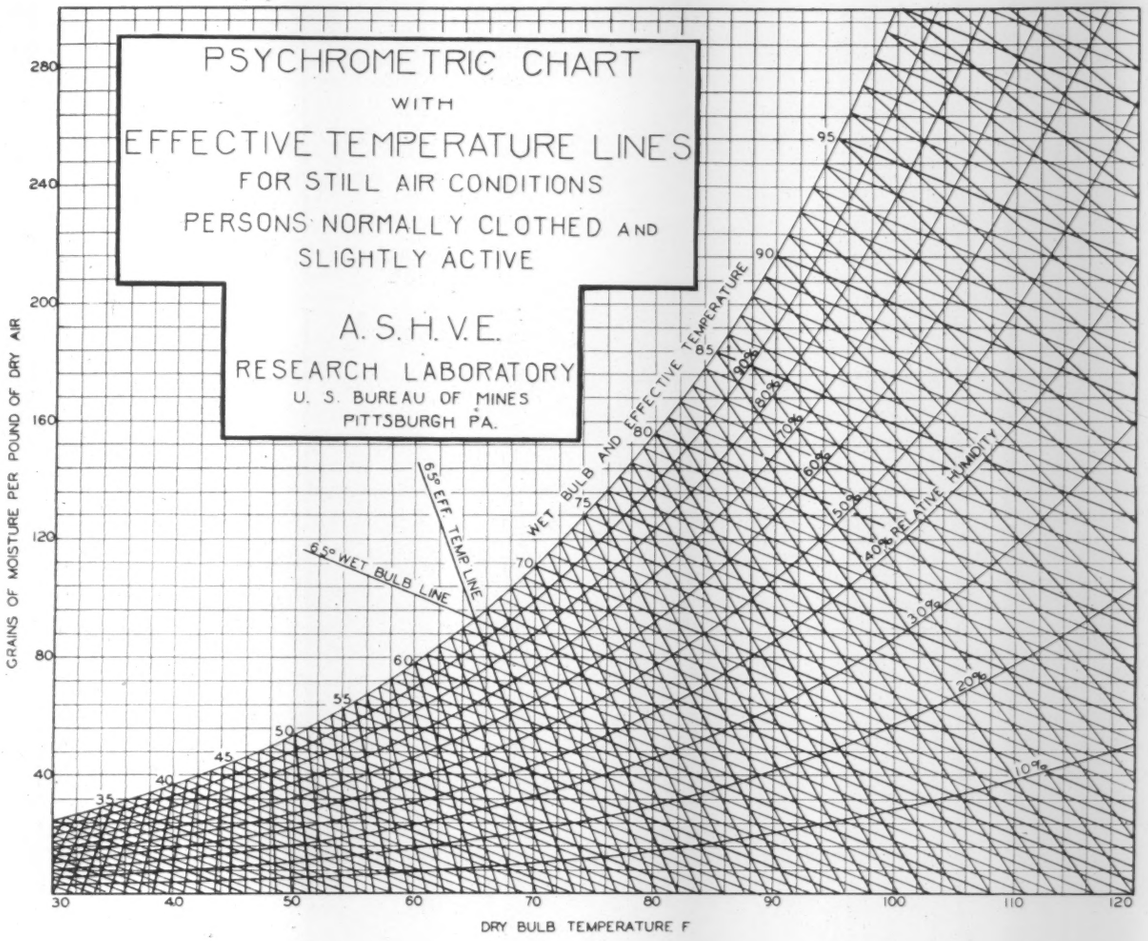

Fig. 2—Psychrometric chart for high effective temperatures

may have a temperature in the summertime as high as 120 F due to transmission, solar radiation, motor or frictional input and the metabolism of the workers. When it is realized that relative humidities of 70 per cent must be maintained in these rooms, it can be seen that unless the dry-bulb temperatures are reduced the resulting wet-bulb with 120 F and even 60 per cent relative humidity (which relative humidity gives a wet-bulb of 108 F) would be unbearable for more than a few minutes. It is therefore necessary in industrial plants of this kind to reduce the temperatures in order to maintain the relative humidities required by the products.

It is the purpose of this research to attempt to establish, by the use of the laboratory methods, a critical point at which the majority of people, working for a definite period—then a rest period, as would normally occur in industry—then a continued work period for a definite length of time, and with the work repeated from day to day, would show no deleterious effect at the end of an average working week. The whole attempt has been and will continue to be to use the laboratory as a pilot plant to fix conditions which will be developed in the field and from which eventually both the engineering of required results and the minimum requirements for legislation can, with sufficient accuracy, be determined.

The methods and the results produced after a year of research are presented herewith, and the engineering required to produce and maintain these conditions under various requirements of industry in warm summer climates are developed in an engineering survey of the particular problems.

In presenting these findings and the photographs and charts of the year's work, it will be noted that the results cover—and then only partially—factors previously enumerated as items 1 and 3 and reference to part of 9, 10 and 11. This leaves a vast amount of research still to be undertaken, for which both local and government assistance is required. Industry can assist enormously in this work by offering sections of their plants for laboratory test investigation which would illustrate and confirm or augment the work that has already been done. No greater benefit to both capital and labor can possibly result than from a thorough knowledge of the questions which this research has indicated as requiring solution.

(To be continued in March)

Responsibility of the ASHVE Towards the Solid Fuel Industry

By W. A. Danielson* (*MEMBER*), Fort Knox, Ky.

HEATING, ventilating, and air conditioning are derived almost entirely from fuel and in most cases from solid fuels. In the last two activities the fuel appears as power and the mechanical engineer with his long intense study has brought the combustion efficiency and incident equipment to a high standard of development. Heating, which is almost entirely in small plants using solid fuels, has had no corresponding study with the result that the greater portion of the fuel—soft coal—is rightly considered dirty, uncontrollable, and that it requires almost the frequent attention of a dusky slave.

This Society as the outstanding professional organization devoted to heating has, therefore, an obligation to the users of solid fuels. If it is to fulfill its mission it must ascertain the requirements of solid fuels for effective and convenient use and control and insure that this information is disseminated widely. That this is more difficult and involved than with gas or oil makes the need for competent investigation the more important. The reputation of the Society's impartial research activities will insure the acceptance of the findings by everyone.

Research in collaboration with the Anthracite Industries Laboratory at Primos has been initiated by this Technical Advisory Committee on a subject that has heretofore been at best an approximation. No known authentic data exist for chimneys for the average house. Certain rules of thumb now control design. Construction details will no doubt be much improved with a probable reduction in cost. This is given as an example of the work ahead in this broad field of study.

Anthracite coal has had size standardization for a number of years but that is not the case with bituminous. There is an optimum size for each service. To determine this requires the collection of much information and the Society's experience makes it the logical agency to analyze and reach definite conclusions.

Considerable information has been and is being published on solid fuels and while there are existing bibliographies on the subject more or less complete, those securing such information seldom know where to obtain guidance. The Society has a responsibility to not only its members but others seeking information on subjects relating to fuels. To disseminate this information the Technical Advisory Committee has created a Sub-Committee to prepare a bibliography of bibliographies. Arrangements have been made for this to appear from time to time in the Society's JOURNAL.

The simplest household fuel burning equipment should meet certain conditions, otherwise there may be danger to life and much higher cost than is necessary. The collection of information and cooperating with other research agencies where necessary can best be done by this Society; in fact there is no other recognized agency properly organized for this. Based on such study, codes should be prepared and it is in anticipation of these important guides for industry that three Sub-Committees have been appointed. Trade organizations have the right to expect this technical help and guidance.

Mining, transporting, and preparing solid fuels give employment to large portions of the population. In the constant reduction in work to be done, encouragement to continue as much as possible the activities which use labor is an obligation to general society. The Federal Government has definitely assumed leadership by recent legislation and the resulting establishment of the National Bituminous Coal Commission. This country-wide undertaking, reaching as it does into all industry and almost every individual's life, will require all the impartial and sound technical information that can be secured. Again, no other agency is in such a splendid position to be of real service in this undertaking as is the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS.

The Technical Advisory Committee, in assuming the work for the Society, tried to cover the entire field of the study and the methods by which it could carry its work into effect. It has adopted the program outline as given herewith.

I. Scope and Purpose: The scope of the Committee's work shall be a study of the utilization of solid fuels with the ultimate objective of providing better service to the residential and small commercial consumer. The Committee is to collect and correlate facts from recognized authorities, cooperate with other agencies doing work in this field, and disseminate knowledge.

II. Information to be Collected:

A. Basic information on solid fuels.
1. Anthracite.
2. Bituminous coal.
3. Sub-bituminous coal, lignite and peat.
4. Coke.
5. Wood and charcoal.

B. Basic information on equipment.
1. Fireplaces.
2. Stoves and space heaters.
3. Boilers (low-pressure heating).
4. Warm-air furnaces.
5. Water heaters (residential, apartment, hotel).
6. Cooking ranges (residential, commercial).

C. Preparation of fuel for the market.
1. Sizing.
2. Cleaning.
3. Treatment.

D. Fuel delivery.
1. To the premises.

*Chairman, Research Technical Advisory Committee on Solid Fuels.
Presented at the 45th Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Pittsburgh, Pa., January, 1939.

2. From bin to fire.
E. Combustion.
F. Removal of ashes.
1. Removal of ashes from fuel bed.
2. Removal of ashes from basement.
3. Removal of soot and fly ash.
G. Requirements of the heat-absorbing surfaces.
1. Heat absorption and transfer.
a. Baffles.
2. Ability to resist corrosion.
3. Ability to withstand temperature changes.
H. Consumer satisfaction.
1. Comfort.
a. Capacity and rating.
2. Safety and health.
3. Convenience.
a. Attendance.
b. Control.
4. Economy.
a. Efficiency.
5. Cleanliness.
6. Dependability.
7. Noise.

III. Sources and Methods of Collecting Information:

A. Collecting data from various organizations (published and unpublished).
1. Government agencies.
2. Trade association laboratories.
3. ASHVE Research Laboratory.
4. Universities and other educational institutions.
5. Manufacturers.
6. Fuel producers.
7. Professional engineers and chemists.
8. Libraries.
B. Papers written for discussion on the utilization of solid fuels.
C. Cooperating on research to find facts not already available.
1. With governmental agencies.
2. With trade association laboratories.
3. With the ASHVE Research Laboratory.
4. With universities and other educational institutions.
5. With equipment manufacturers.
6. In the field under the direction of the Committee on Solid Fuels.

IV. Dissemination of Knowledge:

A. To schools and colleges.
B. To the trade associations of the solid-fuel industries.
1. Through reports submitted by this committee.
2. By talks given at meetings of these trade associations.
C. To the trade associations of the heating industries.
1. Through reports submitted by this Committee.
2. By talks given at meetings of these trade associations.
D. To the Designers (ASHVE members, consulting engineers and architects).
1. By papers written on the utilization of solid fuels.
2. Through the ASHVE GUIDE.
3. Through the manufacturers' technical staffs and literature.
4. Through professional journals.
E. To the Manufacturers (executives, research staffs, salesmen).
1. Through personal contacts.
2. By correspondence.
3. By articles published in newspapers and magazines written so as to be read by these groups.
4. Through trade associations of the heating industries.
F. To the Heating Contractors, Equipment Dealers, and Service Men.
1. Through manufacturers' technical staffs and literature.
2. Through ASHVE GUIDE.
3. Through trade associations of the heating industries.
4. Through trade magazines.
G. To the Solid-fuel Dealers.
1. Information distributed by trade associations of the solid-fuel industries and their representatives.
2. By articles published in trade magazines of the solid-fuel industries.
H. To the Builders.
1. Through heating contractors and equipment dealers.
2. Through the designers.
3. Through solid-fuel dealers.
4. Through articles published in trade magazines.
I. To the Bankers, Real Estate Owners, Operators, and Advisors.
1. By articles published in newspapers and magazines.
2. Through heating contractors and equipment dealers.
3. Through the designers.
J. To Governmental Agencies.
1. Bureau of Mines.
2. Department of Agriculture.
3. Federal Housing Administration.
K. To the Consumer.
1. By non-technical articles published in newspapers and magazines.
2. Through solid-fuel dealers.
3. Through heating contractors and equipment dealers.
4. Through the designers and builders.
5. Through bankers, real estate owners, operators, and advisors.
6. Through manufacturers' advertising in magazines and newspapers.
7. Through educational institutions.
8. By exhibits, permanent and temporary, national and local.
a. Heating and ventilating and similar expositions.
b. Exhibits sponsored by solid-fuel dealers and trade associations.
9. By manuals on operation and service.
L. Through standards when information is definitely established.
1. Specifications, drawn up by the Committee on Solid Fuels.
2. Codes, by ASHVE code committees in conformity to requirements of *American Standards Association.*
3. Legislation, especially municipal construction codes, etc.

V. Committee Organization and Duties:

A. Advisory committee.
1. Outlining programs for working committees.
2. Voting on reports of working committees.
3. Dissemination of information.
B. Sub-committee on anthracite.
1. Collect and correlate information on anthracite and anthracite-burning equipment.
a. Sub-committees on types of equipment.
b. Sub-committees to determine methods of comparing performance of fuels and equipment under the various items of *consumer satisfaction.*
2. Develop and propose minimum performance specifications.
3. Detailed cooperation with other research agencies.
C. Sub-committee on bituminous coal and coke.
1. Collect and correlate information on bituminous coal, coke, and equipment for burning same.
a. Sub-committees on types of equipment.
b. Sub-committees to determine methods of comparing performance of fuels and equipment under the various items of *consumer satisfaction.*
2. Develop and propose minimum performance specifications.
3. Detailed cooperation with other research agencies.
D. Sub-committees on other fuels.

Selection of Solid Fuels from the Viewpoint of the Small Consumer*

By P. Nicholls**, (*MEMBER*), Pittsburgh, Pa.

THIS discussion will be restricted to a consideration of some of the factors associated with the selection of solid fuels and does not include the more general, and controversial, subject of comparison of solid, liquid, and gaseous fuels. Even with this restriction there is commercial rivalry in the claims advanced for coals and cokes.

Domestic appliances in which solid fuels are burned can be listed as hand-fired house heaters, stoker-fired house-heaters, heater stoves, cooking stoves, water heaters and open fireplaces.

Each class of appliance has its particular requirements and requires some special treatment. Although the use of stokers is increasing rapidly, by far the greatest proportion of domestic fuel is still burned either in hand-fired house heaters or stoves, so those uses of solid fuels will be considered first.

For large plants the fuel may be selected on the basis of the true cost, that is, the cost either per unit of output of heat or power, and in industrial furnaces per unit of product. *True* costs include not only costs of the fuel, all direct labor and ash disposal, but also of such other factors as repairs, upkeep, and loss because of shut-downs. In most cases the estimation of the true costs are possible because money values can be assigned to most of the factors, and there are few intangibles to which values cannot be assigned. However, even for large plants, either opinions and preferences influence the weighting of factors, or a relatively small change in or addition to the equipment may alter the conclusions.

Hand-Fired House Heaters

In domestic heating the money value to the household, or the true cost, is more difficult to evaluate. A householder usually considers cost as limited to the direct expenses for fuel and to the removal of ashes from the premises. Normal repairs or replacements for a furnace do not occur frequently enough for him to relate them definitely to the fuel, unless they are partly due at least to his own lack of care. An individual householder cannot assign definite relative expenditures for cleaning the house or its furnishings as caused by his own use of a fuel, because he cannot allocate the blame between himself, his neighbors, or general atmospheric conditions.

Time and labor given to the care of the furnace are true expenditures, although for some rare individuals tending a furnace is a pastime. The relative attendance required by different fuels is most simply expressed by the frequency of attendance, or the time intervals between them, required to give the same results, that is, the same degree of comfort. Although this method of expressing attendance is satisfactory when fuels of the same type are compared, other factors, such as total time spent on the furnace and relative disagreeableness of the jobs are important when different fuels, such as coals and cokes, are compared. Moreover, it is not always true that the same degree of satisfactory heating can be obtained even though the attention to the furnace is unlimited; if a fuel requires more draft than is available in the equipment, satisfactory heating will not be possible. What usually happens is that one is content with a decrease in uniformity of comfort in order to save visits to the furnace.

Attendance Factor

In general, the attendance required decreases with increase in the price of fuels, and one is willing to pay a higher price because the furnace will require less attention. As an alternative, money can be invested in automatic equipment and regulators.

The different types of attention are (*a*) frequency of firing, (*b*) attention between firings, (*c*) shaking of grates and removal of clinkers, (*d*) cleaning of ashpit, and (*e*) cleaning furnace of soot and fly ash.

On the assumption that the same volume of fuel is fired, the interval between firings is proportional to the product of bulk density, calorific value, and over-all efficiency. On the basis of lasting quality of fuels, anthracite lasts longest, bituminous coals next, and cokes the shortest time. However, other factors affect the frequency of firing in practice. Few attendants fill the firepot to its capacity; usually they get the habit of firing either two or three times a day so that the fuel added at each firing will be only enough to last until the next firing. Moreover, few will, and no one should, add a heavy firing of bituminous coal at one time; rather they would build up the bed in stages, which increases the number of visits to the furnace. As an alternative, a larger weight can be fired by adding the labor to pile the hot fuel to one side of the box and fire the new coal in the hollow.

Coke and anthracite coal require no attention to their fuel bed between firings provided the bed is sufficiently cleared of ashes at the time of firing so that the available draft can maintain the rate of burning as more ash ac-

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cumulates in the fuel bed. The number of attentions required by coals which cake will vary with the coal, the weather, and the skill of the attendant; controls to regulate the temperature of the room or to limit the temperature of the water or air cannot function if the bed is caked into big lumps. Badly caking coals thus require the added attendance for breaking the lump of coke.

The relative time and trouble required to remove ashes from the bed depend partly on the quantity of the ash, but more on its clinkering characteristics, although it does not follow that an ash with the highest fusion temperature is the most desirable or that one with a very low fusion temperature cannot be used satisfactorily. The most desirable ash is one that will sinter into a mass that is porous to air but is friable. Such a formation is easily broken yet is not dusty. An ash that fuses little and gives a fine light dust is not only disagreeable to handle and gets through the house, but also interferes with the regulation of burning because of the high resistance to air flow that it adds to the bed.

Although decrease in rate of burning can be overcome by more frequent shakings, the average effect of fine ash is disadvantageous and increases the attendance required.

As is usual with most alternatives, one cannot have an ash that is best for all conditions; one that sinters at lower rates of burning will form slag and clinkers at high rates.

Table 1—Maximum Drop in Pressure Through Fuel Bed, Inches of Water

Rate of Burning, Pounds per Square Foot per Hour	Mean Size of Fuel, In.			
	¾	1¼	1¾	2½
1½	0.072	0.064	0.050	0.030
2½	0.099	0.091	0.092	0.113
3½	0.108	0.107	0.132	0.178

The behavior of ash as it may affect operation can be quite complex. Table 1 shows the maximum pressure drop through the bed at three rates of burning of various sizes of coke having an ash-softening temperature of 2500 F. At the lowest rate the maximum pressure drop decreased materially with increase in size of coke; at the medium rate there was a small increase in pressure drop with increase in size; and at the highest rate the increase was large. These results are due to the relative amount of fusion of the ash under each set of conditions.

The quantity of clinker and its nature depend not only on the fusion temperatures of the ash but also on the form of the ash in the fuel, that is, the quantity and fusibility of the bone and slate. It is desirable that all clinker shall pass to the ashpit and that none need be removed through the firing door; whether or not the latter is necessary depends not only upon the type of clinker but also upon the kind of shaking grates in the furnace. The most fusible ash is not necessarily the most troublesome; a small piece of hard rock or clinker that fouls the grates may necessitate more labor in removing it than will a larger block of clinker. For example, the ash of a coke made from a southern Illinois coal was so fusible that all of it melted and formed one mass of clinker. However, the mass was of the honeycomb type and was porous; consequently, it could be allowed to build up for several firings and was then easily removable in one piece, involving less total labor than do coals with more refractory ashes.

There are no hard and fast rules for evaluating the relative labor factors because they will vary with the furnace and its operation; if the furnace is small for the house or if the method of regulation is from full open to complete closing of the dampers, there will be more clinkering than in equipment in which the rate of burning is more uniform.

With coking coals the clinkering does not depend much upon the size of the pieces of coal, but with free-burning fuels the clinkering will, in general, be more severe as the size of the fuel is smaller, because the maximum temperature in a fuel bed increases with a decrease in size. For this same reason of higher fuel-bed temperatures the clinkering in a warm-air furnace will be greater than in a boiler of equivalent heating capacity, because the water-cooled firepot reduces the temperature of the bed.

In cleaning the ashpit the preference is for an ash that fuses, both because it decreases the fly dust and because it occupies less volume.

The frequency with which the flues of a furnace must be cleaned and the disagreeableness of the job are related directly to the smoking and sooting characteristics of the fuel and, from all aspects, a smokeless fuel is desirable. In few households will the furnace be kept clean enough so that the accumulations of soot in the flues and stack will not decrease the available draft and thus hamper the best performance of the furnace.

Returns as Heating Satisfaction

The returns obtained for the expenditures per ton of fuel plus the labor and time of attendance involve the satisfactoriness of the heating system as a whole, but the comparison of fuels for a given house can be based on (*a*) the heat delivered per ton of fuel and (*b*) the satisfactoriness of its regulation.

The relative heat delivered by different fuels will be closely proportional to the product of the calorific value and overall efficiency. Bureau of Mines Bulletin 276[1] contains the most comprehensive data for American coals burned in hand-fired domestic boilers and reports the results of more than 500 tests using 184 different coals. The analyses of the results show how average efficiencies and heat delivered are related to such main characteristics of the coals as moisture, ash, fixed carbon, volatile matter, and size. Some of the conclusions for the average of these tests were:

1. The thermal efficiency of the fuel actually burned, that is excluding the loss to the ashpit, increased gradually as the volatile decreased until the volatile was about 18 per cent, after which it increased more rapidly, in the case of the anthracites; also, the thermal efficiency on the average was independent of the ash content of the coals up to 15 per cent ash.

2. In these tests the higher thermal efficiency of the semi-bituminous coals and anthracites was offset by higher losses to the ashpit; moreover, the anthracites at that time had a high ash content. As a result the average heat transferred to the water per pound of coal burned was approximately the same (about 7800 Btu) for all coals having below 35 per cent volatile

[1]Five Hundred Tests of Various Coals on House-Heating Boilers, by P. Nicholls, S. B. Flagg and C. E. Augustine. (*Bulletin* 276, *Bureau of Mines*, 1928, 70 pages).

matter on the ash- and moisture-free basis.

In another series of tests[2], all made in the same domestic boiler, the average heat transfer to the water was as given under *A* in Table 2. Because the ash in the anthracites used was high, the results are modified to an assumed 11 per cent ash.

Table 2—Heat Transfer Rates for Various Fuels

	Fuel	Calorific Value	Overall Efficiency	Heat Transferred to Water per Pound of Coal, Btu
A	Bituminous coal	13,610	46.7	6400
	Anthracite	13,000	64.0	8340
	Coke	12,610	66.6	8400
B	Bituminous coal	13,400	45	6000
	Semibituminous	14,600	50	7300
	Coke	12,350	70	8600

The values under *B* are the results of a limited number of tests made by the Battelle Memorial Institute[3] of heating plants, mainly warm-air furnaces, in houses. The relative costs for the fuel for a season's heating with these hand-fired furnaces were estimated to be: Bituminous coal $100, semibituminous $89, and coke $87. These costs include the price of the fuels and the cost of ash removal at Columbus, Ohio.

The lack of agreement among such tests shows the dependence of results upon conditions. Anthracite and coke have the advantage in that their efficiency is less affected by lack of skill in firing than is that of bituminous coal, the efficiency of which may be materially decreased by loss of volatile matter because charges are too heavy or the fire is smothered. The over-all efficiencies of bituminous coals in the tests reported in Bulletin 276 were high because the firings were usually at 6-hour intervals and because the methods of firing were such that the hot bed was not buried. On the other hand, in the tests of the semibituminous coals and anthracites the losses of combustible to the ashpit were high.

The relative degree of satisfactoriness and uniformity of heating with different fuels is dependent on the required attention being given to the furnace. Any fuel, within reasonable limits, will produce satisfactory results provided the furnace is given enough attention. The probability of this being done decreases as the time required is greater, thus free-burning fuels such as anthracite and cokes have the advantage; however, they lose some of this advantage when the installation includes thermostats or automatic regulators.

The foregoing generalities cover all kinds of fuels, but a householder has only a limited number from which he can make his selection, and the kinds available depend largely on his geographic location. In the States of the Atlantic seaboard the broad choice is among anthracites, low-volatile bituminous coals, and cokes, all in the smokeless class. Proceeding westward there are the medium-volatile bituminous coals in central Pennsylvania. The high-volatile coals extend to Indiana, with gradual lowering of rank, that is, with decreasing calorific value, and also with more fusible ash. In the Rocky Mountain province the coals mined range from anthracite to lignite, with large areas of subbituminous.

In general householders do not change the kind of fuel they are using each year, but rather their problem is to select from the available sizes or grades of one kind. Most users have fairly definite preferences as to size, but their choice between grades is associated with trade names, or with certain retail distributors, rather than from a technical knowledge of differences in properties. Apart from the desirability of a certain size because of its satisfactoriness, householders prefer large sizes in the belief that small sizes contain more ash and have a lower heating value; this belief is justified except for coals that have been cleaned or for low-volatile coals, the carbonaceous matter of which is fragile and thus predominates in the fines.

Size is of prime importance in noncaking fuels, but there is some leeway in selection. For anthracites and cokes the choice is usually between stove and chestnut. Stove, the larger size, has the advantage that less secondary air is required and the temperature through the bed is more uniform. For the same degree of satisfaction the fire must be replenished sooner with stove than with nut. In general the nut size is easier to handle, especially with hard cokes, because the fire is less apt to go out in mild weather. The preferable practice is to use the smaller size in spring and autumn and the larger when there is real winter. The severity of clinkering increases with decrease in size, but not so materially when stove is compared with nut as for still smaller sizes.

Size becomes of less importance as the caking quality of a coal increases. In earlier times, when few mines had any but the crudest preparation plants, householders received run-of-mine and learned how to handle the big lumps. Such big lumps could be used effectively in mild weather, and many still prefer them, but better uniformity of burning can be obtained with sized coals. A number of sizes are usually available and may range from 6-in. lumps down. No study has yet been published to show the advantages or fine distinctions of different sizes of coking coals; it may be expected that the most satisfactory size will depend on the caking characteristics and the method of firing and that the size should decrease with a decrease in the area of the fuel bed.

Although fuels under each classification have certain common burning characteristics the values of these characteristics vary, and thus a purchaser may have a range of choice. Some examples are given.

Anthracites have the same general burning characteristics, but the range of 2 to 8 per cent in volatile matter in the coals from mines in various districts is enough to make the differences in their burning noticeable. For the same size of pieces and with other conditions the same the coals with the higher volatile will have a quicker pick-up after a firing or a banking period and also burn more easily. Against this the anthracites with low volatile are denser and a greater weight can be fired.

Coke to a householder means high-temperature cokes, which do not have more than 1½ per cent volatile matter. Cokes can be divided into two types, gas-house and byproduct, but it is only in a few districts that both

[2]Heat Transference and Combustion Tests in Small Domestic Boiler, by H. W. Brooks, M. L. Orr, W. M. Myler, Jr., and C. A. Herbert. (ASHVE Transactions, Vol. 31, 1925, p. 185.)

[3]Efficiencies and Costs of Various Fuels in Domestic Heating, by R. A. Sherman and R. C. Cross. (*Technical Report No. 3, Bituminous Coal Research, Inc.*).

types are available. The physical hardness of cokes is a good measure of their differences in burning properties. A dense, hard coke that rings when dropped is less reactive than a soft coke, will be harder to ignite, and the fire more liable to go out in mild weather; on the other hand, it is denser and a greater weight can be gotten into the furnace. In general, gas-house cokes are softer than those of byproduct origin. The ideal arrangement would be to purchase the softer coke for autumn and spring and the hard coke for winter, but, as explained previously, the same result can be partly accomplished by buying two sizes.

The range in qualities and burning characteristics of bituminous coals is so much greater than for anthracites or cokes that they should be considered under subdivisions and with reference to the geographical location of use. High-grade coals, such as the Pennsylvania and Appalachian, are shipped into districts where lower-grade coals are mined, but rarely is the reverse true. Thus in Pittsburgh, for example, the choice of kinds of bituminous coals covers only a narrow range, whereas in Columbus the range runs from lower-rank coals mined in Ohio to higher-rank imported coals. However, in all districts there is the choice among coals similar as far as the combustible part is concerned, but differing in ash content and ash fusibility. In the merchandising of coal the stage has not been reached where the delivery slip guarantees the quality of the coal by giving its calorific value, ash content, and ash fusibility; therefore the purchaser must depend upon the coal dealer or the reliability associated with a trade name, mine, or producer.

Bituminous coals, even though they are of the same rank and heating value, may differ in their behavior in domestic furnaces, but as yet few systematic data have been obtained on the finer distinctions; the most complete data are those for the 184 coals in Bureau of Mines Bulletin 276, but they are for wide ranges of coal rather than for finer distinctions of coals from different mines in a district.

Some characteristics that a householder will notice are the nature of the caking or how the coal fuses into large masses; how this caking reduces the burning by shutting off the draft; the difficulty of breaking up the caked mass; the size and strength of the coke formed; the nature of the ash and clinker; and the quantity and clogging of the soot. As previously stated, the overall measure of the desirability of coals is the nature and amount of attention required to give the same degree of satisfactory heating.

In the Western and Southern States, where subbituminous coals or lignites are available, additional characteristics are noticeable. Their high moisture and tendency to weather, disintegrate, and ignite in storage introduce special problems when these coals are used in the common type of hand-fired furnaces. In general they are better fitted for a magazine feed which will maintain a thin fuel bed.

Figs. 1 and 2 are reproduced from Bureau of Mines Bulletin 276. They show the relationship of the average efficiencies obtained and the properties of the coals. The numerals in circles give the number of tests that were averaged for each value. Fig. 1 gives the thermal efficiencies; the top curve is for the efficiency of the combustible burned, the next for the percentage loss to the ashpit, and the bottom curves for the overall thermal efficiency. Fig. 2 shows the relative heating values per pound of coal as fired; the three upper curves show the moisture, ash, and calorific values of the coals. The figures illustrate the broad relationships of the results obtained, but do not show the relative troubles they caused; data on attentions are given in the bulletin.

Fuels for Domestic Stokers

Although there are several types of stokers, differing in principle and in the fuel best suited to them, the great majority now are of the underfeed type with screw feed. From the standpoint of the manufacturers it is desirable that one style of stoker should be suitable for a wide range of coals. At present there is a general division of stokers into those for anthracites and those for bituminous coals; it may be expected that there will be a tendency to subdivide the latter class so that, even though the modifications are small, stokers will be available to give the best results for a narrow range of coals.

Stokers are of recent enough development that the householder has no experience upon which to base the selection of his coal but has to depend on recommendations he receives, first from the dealer who sells him the stoker and afterwards from coal salesmen.

Manufacturers of stokers for anthracite have the advantage of knowing definitely the range of variation of the coals that may be used; tests on anthracite stokers have subordinated the dependence of results on the type of anthracite, that is on the volatile content, and have emphasized the effect of size.[4] Sizes from No. 2 buckwheat to pea have been used; No. 1 buckwheat is generally recommended, but pea has advantages with larger stokers.

[4]Domestic Anthracite Stokers, by P. A. Mulcey. (*Transactions* of First Annual Anthracite Conference, pp. 83-93.)

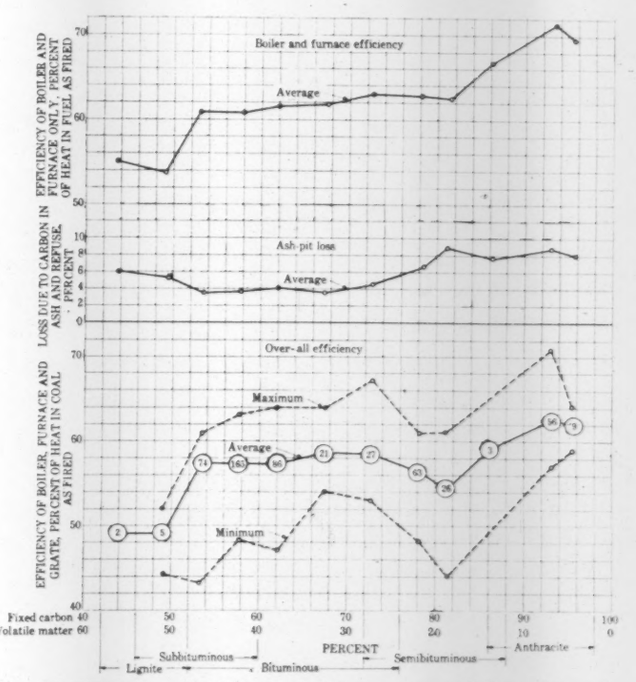


Fig. 1—Efficiency, ash-pit loss, and heat accounted for with various percentages of fixed carbon and volatile matter in coal, moisture and ash free

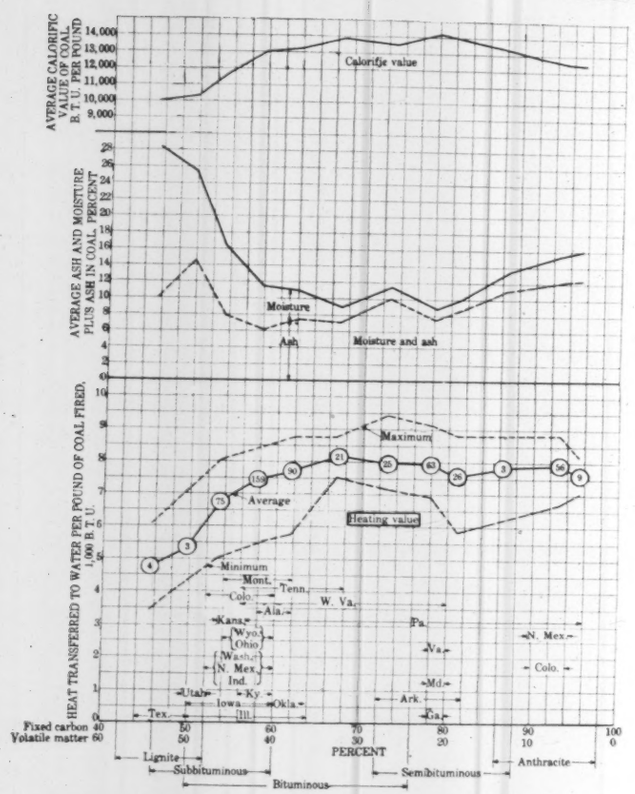


Fig. 2—Relative heating values of coals with corresponding calorific values and per cent of moisture and ash

Full knowledge of the relative desirability of bituminous coals for underfeed stokers as sold is limited, but much useful investigative work has been done. It has been shown that most coals can be used with some success but that as a general rule the desirable qualities[5] are: (1) not more than moderate caking properties; (2) an ash-softening temperature of 2100 to 2550 F; and (3) a size of 1¼ to ¼ in.

These limitations are not definite but only preferable.

Most furnaces with magazine feeds, solid-fuel hot-water heaters, and other burners have been designed for and tested with definite fuels, and householders having such apparatus have no choice except to obtain the recommended fuel at the lowest price. Successful operation of such furnaces depends upon the correct flow of the fuel and on it being of a size suited to the thickness of the fuel bed that the apparatus is designed to produce.

Conclusion

The most important decision a householder is asked to make is whether the elimination of smoke is desired. Having done this, it should be possible to rely on the guidance of the retailers in details of selection.

Until recently coal producers and dealers did not consider that they should act as combustion experts for their customers, who had to depend upon their own common sense when buying fuel and had little published information to help them. Now many of the larger coal companies and some retailers have trained combustion engineers to guide them and help their customers.

Of equal importance has been the action of associations of the fuel industries in establishing laboratories to study their fuels and to disseminate information to insure that they will be so used as to give better satisfaction to customers.

There are separate laboratories and associations for the gas industry, the oil burner industry, the anthracite industry, and the bituminous-coal industry. In addition there are many smaller associations of producers and retailers. These can best help their industries by guiding householders to select fuels so as to obtain the most satisfaction.

[5]The Preparation of Stoker Coal, by R. A. Sherman. (*Coal Heat*, Vol. 34, 1938, pp. 5-8.)

Some Greetings from Life Members

In acknowledging the action of the Council advising that Life Membership in the ASHVE had been conferred upon him, Walter Leek of Vancouver, B. C., has sent an expression of his appreciation with some comments on his work, which will be of interest to his fellow members. Mr. Leek has been a member of the Society since 1903.

I am taking the first opportunity to express my thanks to our organization for the Life Membership. I only regret that it is not for services rendered; the long distance and my busy life interfered, however, with a real desire to have played a more active part in the valuable work performed by others.

Leek and Co. Ltd., established originally in Great Britain, has gone down from father to son for more than 130 years. My sons, (one of whom you have elected in my place as a paying member) have now assumed active management.

I am a member of the British Columbia Chapter of Professional Engineers; past president of the Building and Construction Industries Exchange; Western vice-president of the *Canadian Construction Association* and chairman of the Vancouver Home Improvement Plan and a member of the Provincial Board.

I have many important power plant and central station developments to my credit. For the last 25 years I have devoted a large part of my time to public service, and for the last 10 years have been president of the *Vancouver Exhibition Association*, the second largest exhibition in Canada.

* * *

W. Nelson Haden, a Life Member of the Society who resides in Trowbridge, England, has written of his pleasure in maintaining contact with the ASHVE through its communications and publications, since he was elected to membership in 1902. His firm has had an interesting history and some of his comments are as follows.

In going over some records lately I came upon the

[*Concluded on p.* 122]

Smoke-Producing Tendencies in Coals of Various Ranks

By H. J. Rose* (*MEMBER*), Pittsburgh, Pa. and F. P. Lasseter,** Westport, Conn.

THE United States contains about half of the world's known coal supply, located in more than 30 states. Therefore coals of more than one variety are commercially available in most localities. Standard specifications are now available[1] for classifying coals according to rank, that is, according to their degree of progressive alteration in the natural series from lignite to anthracite. The increasing attention given to the health and economic aspects of air pollution by smoke justifies consideration of the smoke-producing potentialities of coals of various ranks.

Anthracites, because of their chemical composition, are inherently smokeless under all conditions of use. Smoke production from fuels of lower rank will depend not only upon the characteristics of each fuel but also upon the conditions under which it is burned. Under ideal conditions, any fuel can be burned without smoke, but in actual practice many fuels present a major smoke problem to designers and users of heating equipment.

It has long been recognized that the source of coal smoke lies in the tar vapors and hydrocarbon gases in the volatile matter produced when coal is heated. These volatile products may be liberated so rapidly in the furnace, and occupy such a large volume, that it is difficult to supply and mix in the necessary air, and to provide enough space for complete combustion. The result is smoke, a mixture of acrid, brownish tar vapors with black soot produced by the incomplete combustion of tar and coal gas.

The magnitude of the problem can be realized from the fact that typical high-volatile bituminous coals when heated will quickly yield a mixture of tar vapors and coal gas representing one-third to one-half of the total heating value of the original coal. This is well illustrated by the top sections of Figs. 1 and 2, which show the percentage[a] of the total calorific value which appears in the *volatile matter*,[2] when coals of various ranks are heated according to the standard test.

For the higher ranks of coal there is a definite linear relationship between this factor and rank, which may be summarized as follows:

Rank of Coal	Per Cent of Total Btu Liberated in Volatile Matter at 950C
Anthracite	5-14 per cent
Semianthracite	14-21 per cent
Low-Volatile Bituminous Coal	21-28 per cent
Medium-Volatile Bituminous Coal	28-36 per cent
High-Volatile Bituminous Coal *A*	36-47 per cent

The lower-rank coals do not show such a definite relationship, and the percentages range from about 48 per cent down to 30 per cent, with a tendency to decrease towards the lowest ranks.

While the relationship just referred to is interesting, it does not directly measure smoke-producing tendencies. All of the coals referred to yield some volatile combustible matter, yet some of them were known to be smokeless under all conditions of use. Therefore, in order to compare these data with practical smoke-producing tendencies, it was desired to locate information on the burning characteristics of coals of known analysis from all parts of the United States. The most suitable source of information seemed to be a U. S. Bureau of Mines bulletin[3] which summarized more than 500 burning tests in house-heating boilers, of coals from 22 states (plus a few tests of coals from five foreign countries). For the present purpose, some of the original results have been recalculated and graphed in Fig. 1, in order to present *practical* data on smoke and soot. The values in the top section of this figure refer to the same coals as those used in the burning tests.

The tests described in the bulletin were made in four round hand-fired domestic boilers, of either cast-iron or steel construction, which were arranged for steam or hot-water heating. The nominal grate diameters were 23 and 26 in. About 40 per cent of their rated capacity was usually carried by the boilers, and the tests usually lasted for more than 36 hours. Coal was charged in weights such as to give a firing period of 6 to 12 hours. The spreading method was used for anthracite, and alternate side-coking and center-cone methods were used for bituminous coals.

Smoke density was estimated from the Ringlemann-chart scale, and reported in the bulletin as average per cent black over a specified number of hours; for example, "the smoke was 20 per cent black for an average of seven hours." The present writers have condensed this for the graph by multiplying the *average per cent black* by the number of hours, so that the previous example would be shown on the middle section of Fig. 1 as 140 (i.e. 7×20 per cent). The boiler heating surfaces

*Senior Industrial Fellow, Anthracite Fellowship, Mellon Institute of Industrial Research.
**Formerly Industrial Fellow, Mellon Institute of Industrial Research.

[1] Standard Specifications for Classification of Coals by Rank. *ASTM* Designation: D388-38. (1938 Supplement to Book of *ASTM* Standards.)

[a] These percentages are approximations calculated from the ordinary proximate analysis and Btu figures, as follows: An average heating value of 14,500 Btu per pound was assumed for the *fixed carbon* residue in the volatile-matter test. The yield of fixed carbon was therefore multiplied by 14,500 and the product was divided by the heating value of the original coal. This result, when subtracted from 100 per cent, obviously gave the approximate percentage of total heating value which was contained in the volatile matter.

[2] Standard Methods of Laboratory Sampling and Analysis of Coal and Coke. *ASTM* Designation: D271-33. (1936 Book of *ASTM* Standards.)

Presented at the 45th Annual Meeting of the American Society of Heating and Ventilating Engineers, Pittsburgh, Pa., January, 1939.

[3] Five Hundred Tests of Various Coals in House-Heating Boilers, by P. Nicholls, S. B. Flagg and C. E. Augustine. (*U. S. Bureau of Mines Bulletin* 276, 1928.)

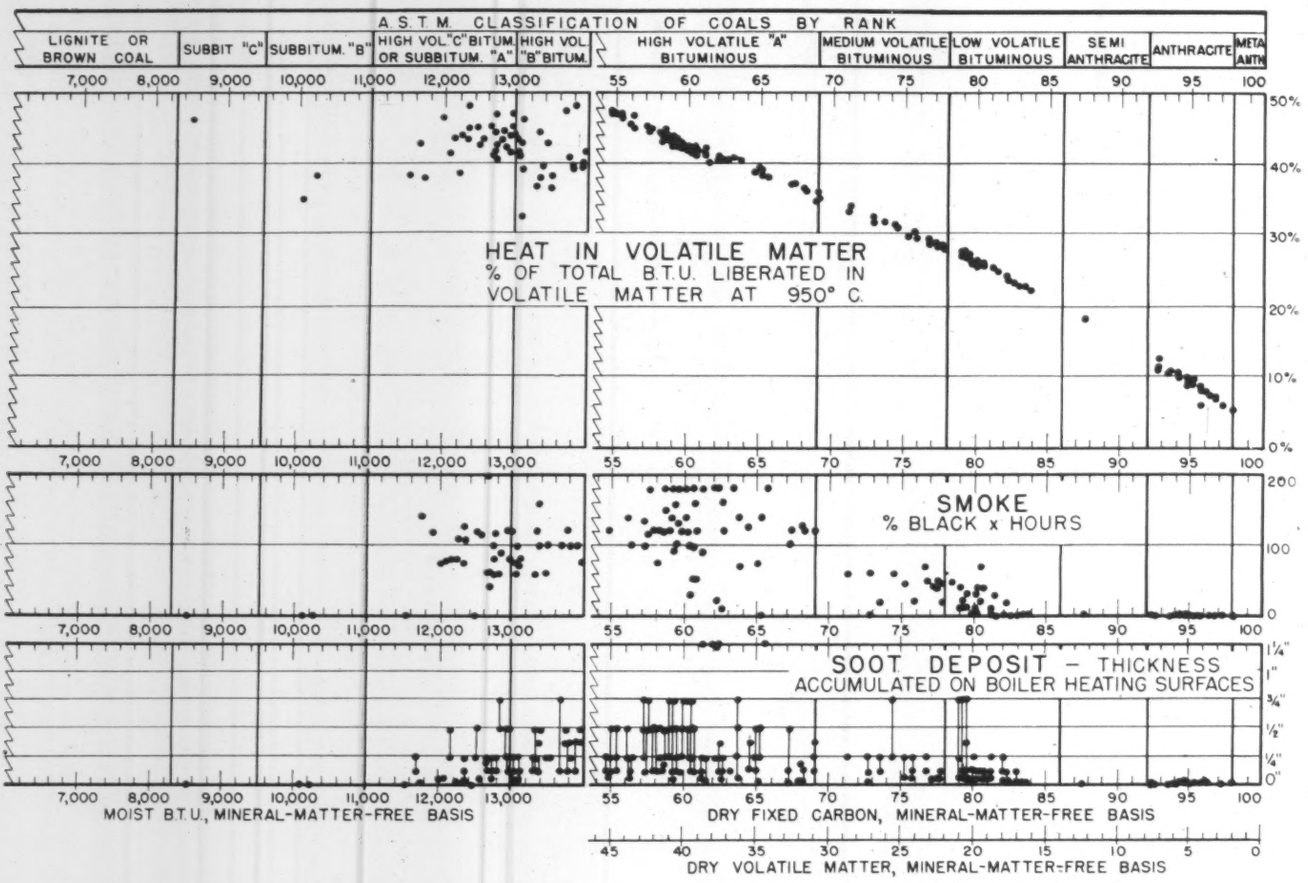

A. S. T. M. CLASSIFICATION OF COALS BY RANK
LIGNITE OR BROWN COAL
SUBBIT "C"
SUBBITUM. "B"
HIGH VOL. "C" BITUM. OR SUBBITUM. "A"
HIGH VOL. "B" BITUM.
HIGH VOLATILE "A" BITUMINOUS
MEDIUM VOLATILE BITUMINOUS
LOW VOLATILE BITUMINOUS
SEMI ANTHRACITE
ANTHRACITE
META ANTH
HEAT IN VOLATILE MATTER
% OF TOTAL B.T.U. LIBERATED IN VOLATILE MATTER AT 950° C.
SMOKE
% BLACK x HOURS
SOOT DEPOSIT — THICKNESS
ACCUMULATED ON BOILER HEATING SURFACES
MOIST B.T.U., MINERAL-MATTER-FREE BASIS
DRY FIXED CARBON, MINERAL-MATTER-FREE BASIS
DRY VOLATILE MATTER, MINERAL-MATTER-FREE BASIS

Fig. 1—Correlation of rank of coals with per cent of total Btu liberated in volatile matter, and smoke and soot produced in house-heating boiler tests. (Based on U. S. Bureau of Mines Bulletin 276)

were cleaned before each test was started, and the thickness of the soot accumulation was noted at its conclusion. This thickness, or range of thickness, is presented in the bottom section of Fig. 1, and is seen to have varied up to 1¼-in. thickness, for tests which never lasted more than 50 hours.

These graphs show that neither smoke nor soot were formed when burning anthracites or the one sample of semianthracite. Under the test conditions, both smoke and soot became apparent with many low-volatile bituminous coals beginning at about 82 per cent fixed carbon (18 per cent volatile matter) on the dry, mineral-matter-free basis, which is equivalent to about 16 or 17 per cent volatile matter on the usual *as fired* basis. As would be expected, high-volatile bituminous coals produced the most smoke and soot. In the zone comprising high volatile *C* bituminous and subbituminous *A* coals (which can only be differentiated by agglutinating or weathering properties), the smoke and soot diminished and little was noted from the three samples of sub-bituminous coals of still lower rank. No lignite samples were included in this series of tests.

The individual values for smoke and soot on Fig. 1 should not be accepted too literally for a number of reasons which need not be enumerated here. However, the graphs are believed to be of interest and value because they show general trends, irrespective of the fact that the size of coal and certain other important variables were not taken into consideration.

The most satisfactory method of determining the smoke-producing potentialities of a fuel is to burn it under the precise conditions which are of special interest. For example, Limbacher and Sherman[4] have obtained continuous records of smoke concentrations resulting from burning bituminous coals by use of small underfeed stokers. They used a scale of units which is directly proportional to the concentration of smoke.

Nevertheless there is always a desire to find some laboratory index of smoke-producing *tendencies* which can be applied to coal itself, irrespective of the conditions under which it may be burned. Various laboratory smoke tests have been proposed in which coal is heated in a current of air. They have the obvious defect that the amount of smoke formed depends upon the particular conditions selected, such as air supply, furnace temperature, condition of sample, etc.

Since smoke originates from the tar and hydrocarbon gases liberated from coal, it is logical to study how the yields of these products vary with rank. For this purpose it was desired to use tar and gas yields obtained at a rather low temperature before extensive cracking reactions had occurred. Therefore low-temperature

[4]The Performance of Several Types of Bituminous Coal on Small Underfeed Stokers, by H. R. Limbacher and R. A. Sherman. (Mimeographed report published by *Bituminous Coal Research, Inc.*, Washington, D. C.)

carbonization yields, made in a Fischer retort, were selected. In this test,[5] the coal sample is placed in a thick-walled aluminum retort and heated according to a definite schedule to the desired final temperature, which is usually 500 C (932 F). The yield of dry tar is obtained, and the gases may be analyzed.

Fig. 2 presents data for a series of coals ranging from anthracite to lignite (but different from those shown in Fig. 1). Some of the coals were tested by the writers; the other results being obtained from publications by U. S. Bureau of Mines authors[6, 7, 8]. The middle section of Fig. 2 shows that the anthracite produced no tar whatever, and the semianthracite only a small amount (down to a trace) of tar. This was to be expected; in fact Turner[9] has proposed a simple and sensitive tar test to differentiate between true anthracites and semi-anthracites in border-line cases.

It is also seen that the tar yield from low-, medium- and high-volatile bituminous coals increases regularly from about 50 to 350 lb of tar per ton of ash-free coal. The latter figure amounts to 17.5 per cent by weight, or about a barrel of tar per ton of coal, which forcibly illustrates the problem which confronts the user who tries to burn such coal smokelessly in small heating equipment. A single cubic foot of such coal may yield a gallon of tar and nearly 40 cu ft of hydrocarbon gases. The tar yield falls off steadily in the lower-rank bituminous and subbituminous groups, and averages less than a hundred pounds per ton for the lignites. However, it must not be forgotten that these low-rank coals

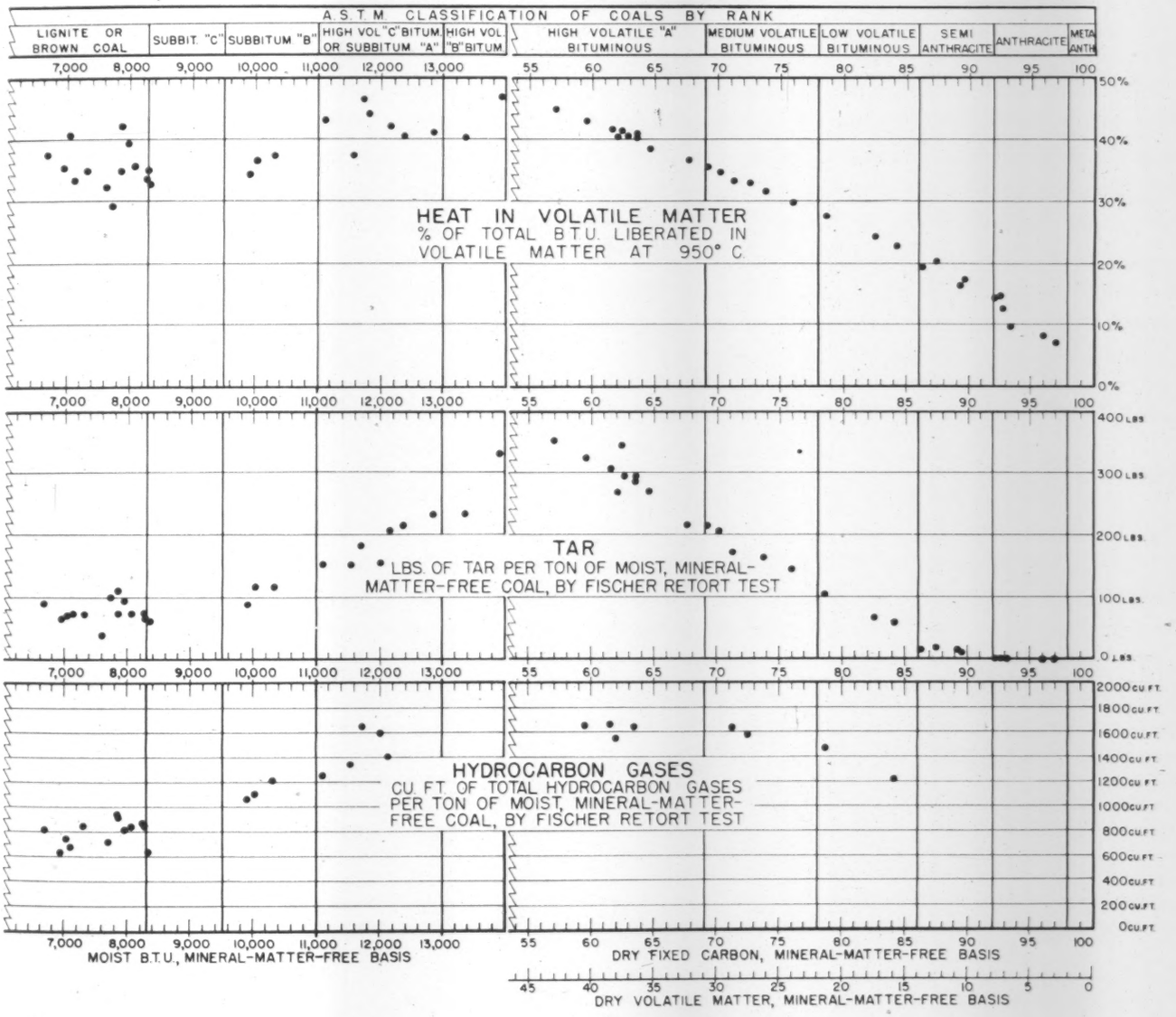
[5]Methods and Apparatus Used in Determining the Gas, Coke, and By-Product Making Properties of American Coals, by A. C. Fieldner, J. D. Davis, R. Thiessen, E. B. Kester and W. A. Selvig. (*U. S. Bureau of Mines Bulletin* 344, 1931.)

[6]Loc. Cit. See Note 5.

[7]*U. S. Bureau of Mines Technical Papers Nos.* 511, 519, 524, 525, 531, 542, 543, 548.

[8]Low-Temperature Carbonization of Lignites and Sub-Bituminous Coals, by J. D. Davis and A. E. Galloway. (*Industrial and Engineering Chemistry*, Vol. 20, 1928, p. 612.)

[9]Anthracites and Semianthracites of Pennsylvania, by H. G. Turner. (*Transactions Coal Division, AIME*, Vol. 108, 1934, p. 330.)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SEMI ANTHRACITE
ANTHRACITE
META ANTH
HEAT IN VOLATILE MATTER
% OF TOTAL B.T.U. LIBERATED IN VOLATILE MATTER AT 950° C.
TAR
LBS. OF TAR PER TON OF MOIST, MINERAL-MATTER-FREE COAL, BY FISCHER RETORT TEST
HYDROCARBON GASES
CU. FT. OF TOTAL HYDROCARBON GASES PER TON OF MOIST, MINERAL-MATTER-FREE COAL, BY FISCHER RETORT TEST
MOIST B.T.U., MINERAL-MATTER-FREE BASIS
DRY FIXED CARBON, MINERAL-MATTER-FREE BASIS
DRY VOLATILE MATTER, MINERAL-MATTER-FREE BASIS

Fig. 2—Correlation of rank of coals with Fischer retort yields of tar and hydrocarbon gases. (Per ton of coal on the moist, mineral-matter-free basis)

have such a low heating value that a much larger tonnage (twice as much in the case of lignite) must be burned in order to obtain the same amount of heat as would be obtained with high-rank coals.

The correlation of tar yields with the graphs of smoke and soot production in Fig. 1 is as good as would be expected in view of the many variables affecting the latter values. The range in rank of coals yielding tar is somewhat greater than the range of coals yielding smoke and soot in the practical tests in hand-fired boilers. This is logical, since any furnace should be able to consume at least a small amount of tar vapors without appreciable smoke production.

The total volume of hydrocarbon gases per ton of coal produced in the Fischer retort test is shown in the bottom section of Fig. 2. This information was not available for all of the samples. However, it is known from published tests (made under other conditions) that the yield of hydrocarbon gases obtained from anthracite is small.[10] High-volatile bituminous coals produce as much as 1600 cu ft of such gases per ton of ash-free coal, thus adding to the problem of providing sufficient air and furnace volume for complete combustion.

Naturally there are variations in the compositions, as well as the yields, of tar and gas produced from such a wide range of coals, and these have some effect on the problem of smokeless combustion. However, the subject will not be developed here.

Others have reported that smoke production is proportional to the *volatile matter* of coal, which may well be the case with a limited range of coals, particularly of the bituminous class. However, the studies on which this paper is based have shown that the volatile matter percentage considered alone is not a suitable smoke index when coals of all ranks are included.

When it is desired to rate coals according to their smoke-producing tendencies, but without specifying particular combustion conditions, the tar yield in the Fischer retort test[11] should be a practical and sufficiently accurate index.

[10] Volatile Matter of Pennsylvania Anthracite, by H. G. Turner and W. L. Keene. (*Industrial and Engineering Chemistry*, Vol. 27, 1935, p. 1373.)

[11] Loc. Cit. See Note 5.

Some Greetings from Life Members

[*Concluded from p.* 118]

memoir of my grandfather, the founder of our firm, as published in the annual report of the *Institution of Civil Engineers* in 1856. From correspondence I find they started making and fixing warm air stoves in 1817. Ours has been a family business as can be judged by the way the firm has developed. The directorate is now enlarged from those who have been connected with the firm as branch managers or have held other offices. My son, now the managing director and for a time a pupil of J. H. Walker in Detroit, was installed as president of the *British Institution of Heating and Ventilating Engineers* on February 9, 1938. He is the fifth generation in our family line of engineers. My presidential years were 1906 and 1907; I retired in 1933 after being 58 years in the firm, as I was apprenticed to my father in 1875.

I have happy memories of joining in the Annual Meeting in Washington when J. R. McColl was president.

* * *

Edgar Herring, of London, England, has written, expressing his appreciation of election to Life Membership in the Society and he wishes to assure the Officers and Council that although he has retired from active business, he will always maintain his interest in the work of the ASHVE and wishes the Society continued success. Mr. Herring became a member in 1919. Some of his remarks are as follows:

It may interest you to know that I am one of the oldest heating and ventilating engineers in this country, having been actively engaged in the industry for 55 years. It is, I suppose, always the case that on retirement after a long period of service an old man looks back over the road travelled and recalls the milestones in his career. I am no exception to this rule, and in reviewing the past I have been much struck by the remarkable development of the industry and the progress made towards the goal set up by the Society, viz: the establishment of a sound scientific foundation upon which to base the solution of the many problems which confront an engineer in the course of his practice.

To this development and progress I fully recognize the important contribution made by the American Society of Heating and Ventilating Engineers and feel that on retiring I should like to place on record my admiration of the splendid work of the Society as well as my indebtedness to it for much valuable information that I have obtained from the Transactions, The Guide and especially the research work. While our Institution in this country has also done valuable work I venture to say that the development of the industry on this side of the Atlantic would not have reached its present stage had it not been for the example set by the American Society of Heating and Ventilating Engineers. Progress in the science of heating, ventilating and air conditioning over here has necessarily been somewhat slower than in America owing to the fact that our variations in climatic conditions are confined to narrower limits. Up to comparatively recent years central heating, other than for large buildings, has been regarded as a luxury rather than a necessity, as in your case, and it has taken a great deal of propaganda to break down the Englishman's affection for a blazing open fire, the radiant effect of which, after all, has much to recommend it in contradistinction to the heat monotony characteristic of radiator heating.

During the last 10 to 15 years air conditioning in this country has awakened considerable public interest and has achieved a substantial measure of popularity and most of our authorities now demand an up-to-date air conditioning installation in public buildings.

Pittsburgh Experiment Station of the U. S. Bureau of Mines where the Research Laboratory of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS *is located*

Twentieth Annual Report

ASHVE COMMITTEE ON RESEARCH 1938

APPROACHING the 20th anniversary of the establishment of the Research Laboratory of the Society at the Pittsburgh Experiment Station of the United States Bureau of Mines in July, 1919, the Committee on Research closes another successful year of service to the heating, ventilating and air conditioning profession and industry. Its activities were administered through 24 Technical Advisory Committees, and while research carried on by some of these groups was limited to Committee deliberation, actual physical research resulting in definite progress was engaged in under a number of others.

According to plans developed at the Annual Meeting in 1938 the Committee revised its procedure in a number of respects. The Executive Committee was increased from three to five members and took on greater responsibility in the name of the Committee on Research. The Technical Advisory Committees were reorganized and in some instances several Committees reporting parallel interests were grouped under the one heading. As an example, five Committees dealing with definite phases of physiological research, including sensations of comfort for air conditioning in the treatment of diseases and air conditioning requirements of hospitals were combined.

The advantages resulting from this reorganization made it possible for the Chairman of the Committee, with additional assistance, to keep in closer contact with the work of the 24 Technical Advisory Committees, with the result that more consistent and active consideration of the various research projects was possible. The financing of the Committee's work, in line with the general policy of the Society, was simplified in that much of the routine work of accounting was transferred directly under the Treasurer of the Society in the headquarters' office.

An entirely new line of activity dealing with the applications of air conditioning in industry was begun under a new Committee headed by A. E. Stacey, Jr., and was made a major function of the Committee's research activity during 1938. Also the work of establishing fundamentals on which comfort air conditioning requirements are based was actively projected during the current year under C. Tasker's Committee on Sensations of Comfort.

The detailed plans, accomplishments and future objectives of the various Technical Advisory Committees functioning under the Committee on Research during the year 1938 may be referred to in the report which follows.

* Presented at the 45th Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Pittsburgh, Pa., January, 1939.

W. L. Fleisher
Chairman

Committee on Research
W. L. Fleisher, *Chairman*
J. H. Walker, *Vice-Chairman* **F. C. Houghten, *Director***
A. C. Fieldner, *Ex-Officio Member*

H. E. Adams	D. W. Nelson	T. H. Urdahl
W. A. Danielson	A. E. Stacey, Jr.	J. H. Van Alsburg
M. K. Fahnestock	C. Tasker	C.-E. A. Winslow
C. E. Lewis	R. J. Tenkonohy	B. M. Woods
	G. L. Tuve	

J. H. Walker
Vice-Chairman

RELATIONS OF AIR CONDITIONS TO HUMAN HEALTH AND COMFORT

W. L. FLEISHER, General Chairman

Technical Advisory Committee 1*a*

SENSATIONS OF COMFORT

C. TASKER, Chairman

Thomas Chester	W. J. McConnell
F. E. Giesecke	A. B. Newton
Elliott Harrington	J. R. Parsons
R. E. Keyes	C. P. Yaglou

Two meetings of this Committee were held during 1938. At the request of the Chairman, and with the approval of the Committee, arrangements were made with the Program Committee of the Society to devote a technical session at the Semi-Annual Meeting especially to Comfort Air Conditioning. The papers presented at this meeting are listed elsewhere in this report. Following the interesting results of the Minneapolis study in 1937, arrangements were made to conduct studies in the summer of 1938 in San Antonio, Tex., Washington, D. C., and New York City.

In cooperation with the Texas Agricultural and Mechanical College, the Society sponsored a study in the offices of the San Antonio Public Service Co., San Antonio, Tex. Ninety-four persons (72 men and 22 women) participated in the test, the data being collected by a trained observer thus giving rather better control than that obtainable in earlier studies. The results of this study are being presented at the Annual Meeting in Pittsburgh, January 1939. The results indicate that in spite of mild winters and the intensity and duration of the summer heat in San Antonio there is very little difference in the optimum effective temperature for indoor comfort in Texas as compared with other localities where similar investigations have been made.

In Washington, D. C. the study was conducted at the Federal Reserve Building, and the data are now being analyzed by the Research Laboratory. In New York the study was conducted in the Metropolitan Life Insurance Building, New York, under the direction of Dr. W. J. McConnell. The data collected are very comprehensive and the Company has volunteered to analyze these data completely. It is hoped that it will be possible to prepare a paper on this study for presentation during the next few months.

In view of the results obtained in the studies made since 1935, it is expected that the next step of the Committee will be to determine the methods of applying the results to actual practice.

Technical Advisory Committee 1*b*

PHYSIOLOGICAL REACTIONS

C.-E. A. WINSLOW, Chairman

T. Bedford	André Missenard
E. F. DuBois	R. R. Sayers
R. W. Keeton	C. Tasker

This Committee considers its immediate function to be interpretation to the ventilating engineer of current progress in physiological research, which may influence the solution of his practical problems. During the past year the Committee has prepared a summary of such recent advances as seemed most important, including emphasis on the different reactions of the human body to the environment in various zones of physiological response. In the cold zone, it has stressed particularly the important effects of local chilling of different parts of the body and the very minor influence of relative humidity as compared with air and wall temperatures and air movement. For the hot zone, it has cited the upper limits of temperature and humidity beyond which the evaporative regulatory process of the body is impracticable. It has also discussed problems of comfort and emphasized their intimate relation to physical activity and metabolism. It is the conclusion of the Committee that at present the question of atmospheric adaptation is fundamentally a thermal one, and that there is little ground, under conditions of normal occupancy, for controlling chemical and electrical properties of the atmosphere (ozone or ions). The report of the Committee will be presented at the 1939 Annual Meeting.

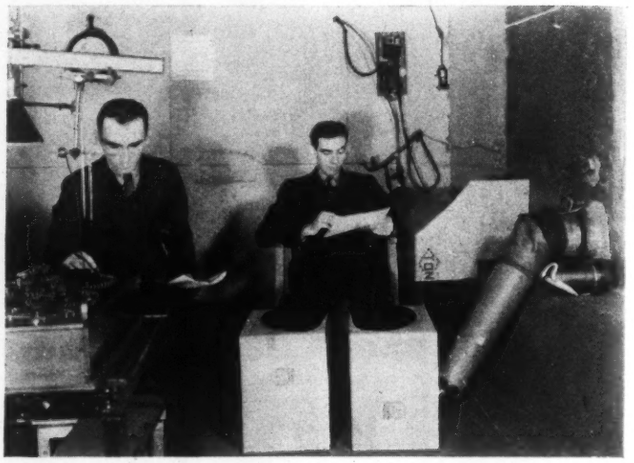

Fig. 1—Study of the effects of drafts on the ankle, Research Laboratory

In addition to this general summary, Dr. R. W. Keeton and his colleagues have conducted an important experimental study of cardiac output, peripheral blood flow, and blood volume changes in normal individuals subjected to varying environmental temperatures, further results of which will also be presented at the 1939 Annual Meeting.

Technical Advisory Committee 1*c*

TREATMENT OF DISEASE

T. L. HAZLETT, Chairman

C. J. Barone	C. D. Selby
B. Z. Cashman	W. O. Sherman
M. B. Ferderber	A. W. Sherrill
E. V. Hill	H. F. Smith
C. S. Leopold	R. J. Tenkonohy

B. L. Vosburgh

This Committee was organized at the beginning of the year to carry on a study of air conditioning of an operating room

Institutions Cooperating with the Committee on Research

Agricultural & Mechanical College of Texas

Summer Comfort Cooling Requirements.
Heating Requirements of Buildings.

Case School of Applied Science

Heat Transfer of Finned Tubes with Forced Air Circulation.
Air Distribution in Air Conditioned Spaces.

University of California

Performance of Cooling Towers.

University of Illinois

Air Conditioning in the Treatment of Diseases.
Direct and Indirect Radiation with Gravity Air Circulation.
Residence Air Conditioning.
Air Distribution Outlets.

Michigan College of Mining & Technology

Corrosion in Steam Heating Systems.

University of Minnesota

Air Cleaning Devices.
Conductivity of Insulation and Building Materials.

University of Pittsburgh

Air Conditioning Requirements for Hospitals.

Princeton University

Studies of Sound Control in Ventilating Systems.

University of Toronto

Insulating Materials Used in Heating and Ventilating Practice.

University of Wisconsin

Aeration of Buildings.
Effect of Entering Air on Temperature, Velocity and Distribution of Air in Enclosed Spaces.
Heat Transfer in Storage Water Heaters.

and recovery ward in the Magee Hospital in Pittsburgh by the School of Medicine of the University of Pittsburgh in cooperation with the Committee on Research.

Through the cooperation of the interested industry an experimental air conditioning system has been installed to take care of an operating room and recovery ward. The system was put into operation and the collection of data was initiated in June.

The Committee has developed a comprehensive program, including:

1. *Feeling of Warmth:* Optimum temperature and humidity conditions within the operating room and recovery ward for the best interests of the patient, either directly, or through greater efficiency of the operating surgeon and his attendants.
2. *Bacteria:* The bacteria content of the atmosphere in an operating room as found in the past, and with the present air conditioning system; and further, how the bacteria content may be affected by ultra-violet sterilization and electro-static precipitation of dust.
3. *Anesthetic Concentrations:* The relation between past performance without air conditioning and present performance with air conditioning and controlled ventilation, as affecting concentration of anesthetic at different points in the operating room.
4. *Static-Electric Sparks:* Relation between atmospheric conditions and the hazard of electrical sparking possibly causing ignition of air-gas mixtures.
5. *Physiological Aspects of the Subject:* Medical observations relative to weight, blood pressures, blood chemistries, and skin temperatures; perspiration of attendants and patients; feeling of comfort, well-being, and presence or absence of fatigue of operators; urine chloride of patient before and after operation; bacteriologic content of operating room air with and without occupants, and effect on healing; and the effect of the recovery room as it aids or deters patient's recovery, which might be contrasted to a room in which no air conditioning exists.

Some data have been collected under several of the items listed, but essentially in connection with item (1), or the determination of the desired effective temperature on the part of doctors, nurses, internes and other attendants, together with the observed reactions of patients to these same conditions. A preliminary paper resulting from the study during the past summer will be presented at the 1939 Annual Meeting.

Fig. 2—Skin temperature measurements on subjects in an air conditioned room, Medical School, University of Illinois

Technical Advisory Committee 1d
CLIMATE AND SEASON

J. H. WALKER, Chairman

H. A. Abramson
O. W. Armspach
Ellsworth Huntington
C. A. Mills
André Missenard
T. H. Urdahl
E. L. Weber

The general objective of this committee is a study of the effect of climate and season on the physiological reactions of human beings, particularly as to their relation to the air conditioning problem. A bibliography has been compiled, which is in the files of the Bureau for Correlating Thermal Research, at the Research Laboratory. Copies may be obtained upon request.

As a contribution to the work of the Committee a paper, dealing with the effect of pollens on health, will be presented at an early meeting of the Society.

Technical Advisory Committee 1e
AIR CONDITIONING IN INDUSTRY

A. E. STACEY, JR., Chairman

Philip Drinker
Leonard Greenburg
H. P. Greenwald
A. M. Kinney
J. W. Kreuttner
L. L. Lewis
W. J. McConnell
C. P. McCord
P. A. McKittrick
R. R. Sayers

The organization of this Committee was authorized during the current year to study the bearable effective temperatures which a group of people working under prescribed conditions could endure from the standpoint of health. The Committee was also desirous of determining from a sufficiently large group the variations in the physiology of different subjects so that a method of determining those possible divergences in human beings could be established for the selection of a work in a particular industry.

Eleven basic points are enumerated herewith which have an important relationship to proper air conditioning in industry as related to the worker.

1. The simultaneous relationship of temperature and humidity to the reactions of human beings *at work.*

Contributors to Research

Contributions in support of the research work of the Committee on Research are hereby acknowledged from the following:

Alleghany City Steam Heating Co.; American Rolling Mill Co.; Anemostat Corporation of America; The Auer Register Co.; Barber-Colman Co.; Bristol Co.; Buffalo Forge Co.; E. K. Campbell Heating Co.; Carrier Corp.; Detroit Edison Co.; Detroit Lubricator Co.; Excelsior Steel Furnace Co.; Federal Reserve Board Building Management; Julien P. Friez & Sons, Inc.; The Fulton Sylphon Co.; The G & O Manufacturing Co.; General Electric Co.; Hart & Cooley Co.; *Heating, Piping and Air Conditioning Contractors National Association;* Ilg Electric Ventilating Co.; Illinois Testing Laboratories; Independent Register Co. Johnson Service Co.; Lastick Products Co., Inc.; May Oil Burner Corp.; Metropolitan Life Insurance Co.; F. Meyer & Bros.; Milcor Steel Co.; Modine Mfg. Co.; Nyekker Brass Co.; *National Association of Woodwork Jobbers, Inc.; National Door Manufacturers Association;* John J. Nesbitt, Inc.; Permutit Co.; Reeves Mfg. Co.; Rochester Gas and Electric Corp.; San Antonio Public Service Co.; *Steel Heating Boiler Institute;* The Trane Co.; Tremco Mfg. Co.; Tuttle & Bailey, Inc.; Union Electric Company of Missouri; U. S. Register Co.; The Waterloo Register Co.; and Westinghouse Electric & Mfg. Co.

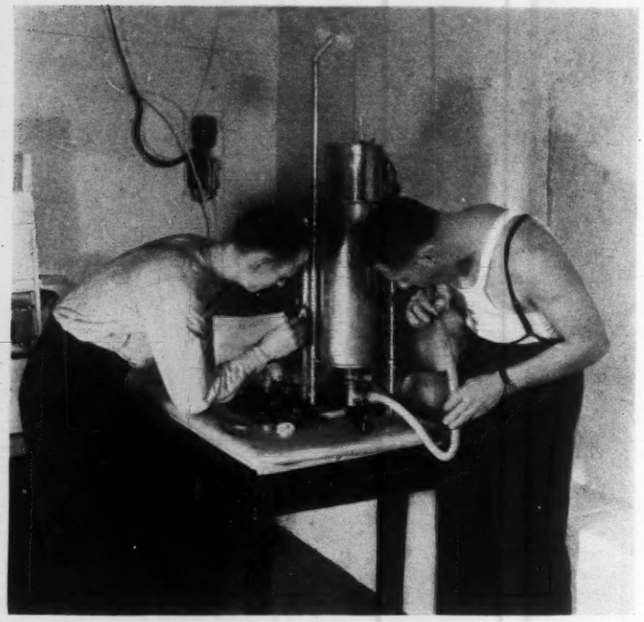

Fig. 3—Determination of the vital capacity of a subject working in hot atmospheres

2. The air conditions required for the making of goods, and the air conditions encountered in the extraction of basic materials.
3. The change in the required atmospheric conditions with changes in the manpower output.
4. The increased amount of work healthfully obtained with better conditions.
5. The problem of dust, vapors, fumes and gases which may be harmful to workers.
6. The presence of bacteria, spores, etc., that may produce unsanitary conditions or be harmful to processes.
7. The prevalence of odors arising from working conditions.
8. The prevalence of noise disturbances.
9. Legislation required to protect labor and capital.
10. The engineering basis on which the requirements called for by legislation or determined by research can be calculated.
11. Analysis of research already done or being done or that research required to be done on which to base sound conclusions.

During the past summer the Research Laboratory was assigned to study the physiological reactions of men while carrying on light work in atmospheric conditions, including effective temperature from 77 to 92 deg, with relative humidities of 60, 75 and 90 per cent. It was not only the purpose of this research to determine, if possible, at what point in conditions which may readily occur in industry a physiological break takes place in the workman, but also to outline, from an engineering standpoint, what methods may be pursued, from an air conditioning angle, to relieve or prevent the occurrence of critical conditions. The methods and results produced from this research will be presented in a paper before the 1939 Annual Meeting. Additional work is especially necessary to determine the effect of air movement in reducing the severity of the physiological reactions for different types of work at the same dry-bulb temperature and humidity. In presenting these findings the Committee recognizes that the results cover only a few of the factors previously enumerated, which leaves a vast amount of research still to be undertaken for which both local and Government assistance is essential. The Committee also recognizes that industry can assist enormously by offering sections of their plants for laboratory test investigation which would illustrate and confirm or augment the work that has already been done.

Technical Advisory Committee 2

AIR CLEANING AND ATMOSPHERIC IMPURITIES

H. C. MURPHY, General Chairman

MECHANICAL PROCEDURES 2*a*

LEONARD GREENBURG, Chairman

J. J. Bloomfield
W. H. Carrier
R. S. Dill
Theodore Hatch
C. E. Lewis
A. L. Simison
W. O. Vedder

ELECTRICAL PRECIPITATION AND STERILIZATION 2*b*

E. B. PHELPS, Chairman

H. E. Adams
R. D. Bennett
L. W. Chubb
L. R. Koller
G. W. Penney
W. F. Wells

Two papers were presented at the 1938 Semi-Annual Meeting of the Society which cover investigations this Committee is carrying forward. One of these was by R. S. Dill of the U. S. Bureau of Standards and the other was by Prof. F. B. Rowley of the University of Minnesota. A paper outlining further studies on the air filter investigation the Committee on Air Cleaning and Atmospheric Impurities is carrying on at the University of Minnesota will be presented at the 1939 Annual Meeting.

Further studies as to the possibility of revising the ASHVE Standard Code for Testing and Rating Air Cleaning Devices Used in General Ventilation Work, to provide an alternate method for rating cleaners by use of the photo-electric cell, are under way. Additional basic research is needed to determine the effects of various dusts and various particle sizes on the absorption of light.

Work on the development of the Code for Testing Air Cleaning Devices Used in Dust Hazardous Occupations has been resumed. This project was deferred temporarily in order that additional data could be secured from the medical profession. It now appears that this work can go forward and a Code be prepared for submission to the Society.

Efforts to coordinate various independent investigations of the control of air-borne organisms and the effect of air pollution on epidemic diseases have been instituted.

A meeting of the Committee on Mechanical Procedures was

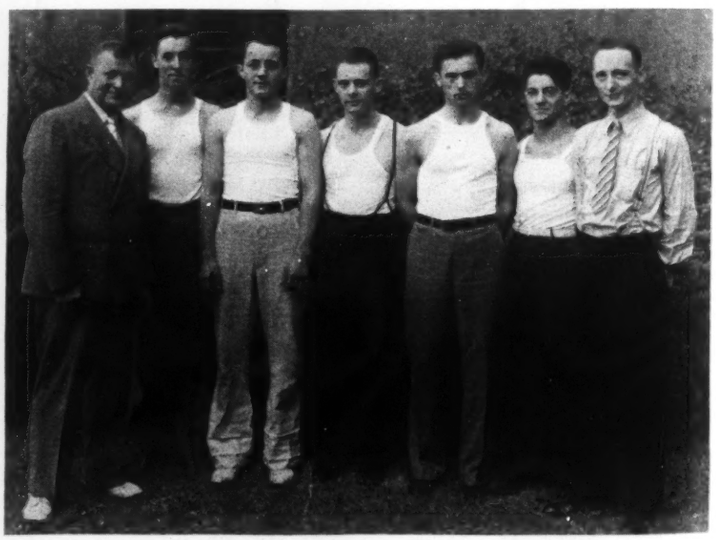

Fig. 4—Some members of the Research Laboratory staff and subjects in the study of air conditioning in industry. (Left to right)—F. C. Houghten, Director; B. Gunst, J. Suciu, R. Scheideman, Lab. Asst.; D. Ivanovic, R. Tomarelli and Carl Gutberlet, Research Asst.

held at the Hot Springs Meeting and also a well attended conference of the entire Committee was held in Washington D. C., September 30, 1938. At this meeting the Committee was fortunate in having the active cooperation of the Acting Chief of the U. S. Public Health Service and his associates. The purpose of the meeting was to consider and further outline a program for research in the field of atmospheric impurities and to endeavor to coordinate this work with other investigating bodies to eliminate useless duplications of effort. The meeting was successful in this respect and it is believed an opportunity for effective cooperation with the various Government bodies has been initiated.

Technical Advisory Committee 3
RADIATION AND COMFORT WINTER AND SUMMER AND EFFECT OF VARYING HUMIDITY ON RADIANT HEATING AND COOLING

J. C. FITTS, Chairman

A. A. Adler	W. R. Rhoton
A. H. Barker	W. W. Timmis
W. D. Fleming	G. R. Wait
R. P. James	S. L. Warren
C. A. Mills	C.-E. A. Winslow
D. W. Nelson	C. F. Wood

This Committee was appointed the first part of the year to consider all problems in connection with radiation as it effects comfort in winter and summer. As a result of preliminary conferences a long range program of research was outlined to include several basic investigations which are enumerated herewith:

1. A study based on primary sense reactions of the relative comfort derived from rooms with normal window arrangements from convected heat and from heat supplied by both convection and direct radiation.
2. A study of the effect of radiation in governing the sense of warmth of a person in an occupied space, together with the effect of dry-bulb temperature, moisture content and movement of the air already studied by the Society and included in the Effective Temperature Index or the Comfort Chart.
3. A study of the physiological reactions of persons, including skin temperature, comfort and health measurements, to rooms heated with and without radiation.
4. A study of the relative effect on comfort and physiological reactions by radiation of varying wave-length, and the effect of the relative humidity of the air within the room on the effectiveness of such radiation.

As an immediate objective the Committee has been considering plans for the initiation of studies covering item 1 to be conducted at the Research Laboratory in Pittsburgh.

Technical Advisory Committee 5
WEATHER DESIGN CONDITIONS

T. H. URDAHL, Chairman

J. C. Albright	A. C. Grant
F. S. Cornell	J. H. Kincer
John Everetts, Jr.	O. A. Kinzer
E. W. Goodwin	J. W. O'Neill

L. S. Ourusoff

This Committee has made much greater progress during the current year than its limited resources seemed to permit at the time the program was initially adopted. This progress is due largely to having had made available a great quantity of summer design temperature data which had been previously analyzed and the cooperative continuance of the work to embrace the analysis of some additional data required in attaining the Committee's objectives.

Papers Resulting from Research During 1938

The 24 research projects considered by as many Technical Advisory Committees resulted in 21 papers during the year, as listed below. The research from which these papers resulted was carried out at the Research Laboratory in Pittsburgh, by the Laboratory in cooperation with other organizations and by Universities in cooperation with the Committee on Research. These papers, resulting from the Society's research activities, are becoming more and more an important part in the deliberations of the Society meetings, and are looked forward to with greater expectation and confidence by the membership of the Society as being vitally important in the progress of this industry.

1. Draft Temperatures and Velocities in Relation to Skin Temperature and Feeling of Warmth, by F. C. Houghten, Carl Gutberlet and Edward Witkowski. February 1938 Journal.
2. Physiologic Response of Man to Environmental Temperature, by F. K. Hick, R. W. Keeton and Nathaniel Glickman. March 1938 Journal (Results of coop. research at College of Medicine, Univ. of Illinois).
3. Air Distribution from Side Wall Outlets, by D. W. Nelson and D. J. Stewart. April 1938 Journal (Results of cooperative research at the University of Wisconsin).
4. Study of Summer Cooling in the Research Residence Using a Small Capacity Mechanical Condensing Unit, by A. P. Kratz, S. Konzo, M. K. Fahnestock and E. L. Broderick. May 1938 Journal (Results of cooperative research at the University of Illinois).
5. Cooling Requirements for Summer Comfort Air Conditioning in Toronto, by C. Tasker. June 1938 Journal (Results of cooperative research at the Ontario Research Foundation).
6. Heat Transfer Through Single and Double Glazing, by M. L. Carr, R. A. Miller, Leighton Orr and Alan C. Byers. June 1938 Journal.
7. Study of Summer Cooling in the Research Residence Using a Small Capacity Mechanical Condensing Unit, by A. P. Kratz, S. Konzo, M. K. Fahnestock and E. L. Broderick. June 1938 Journal (Results of cooperative research at the University of Illinois).
8. Shock Experiences of 275 Workers After Entering and Leaving Cooled and Air Conditioned Offices, by A. B. Newton, F. C. Houghten, Carl Gutberlet, R. W. Qualley and M. C. W. Tomlinson. July 1938 Journal.
9. Air Filter Performance as Affected by Kind of Dust, Rate of Dust Feed and Air Velocity Through Filter, by Frank B. Rowley and Richard C. Jordan. August 1938 Journal (Results of cooperative research at the University of Minnesota).
10. General Reactions of 274 Office Workers to Summer Cooling and Air Conditioning, by F. C. Houghten, A. B. Newton, R. W. Qualley and Edward Witkowski. August 1938 Journal.
11. Performance of Surface-Coil Dehumidifiers for Comfort Air Conditioning, by G. L. Tuve and L. J. Seigel. September 1938 Journal (Results of cooperative research at Case School of Applied Science).
12. The Flow of Air Through Exhaust Grilles, by A. M. Greene, Jr. and M. H. Dean. Spetember 1938 Journal (Results of cooperative research at Princeton University).
13. Seasonal Variations in Effective Temperature Requirements, by F. E. Giesecke and W. H. Badgett. October 1938 Journal (Results of cooperative research at Agricultural and Mechanical College of Texas).
14. A Study of the Heat Requirements of a Single-Glazed Test House and a Double-Glazed Test House, by M. L. Carr, R. A. Miller, Leighton Orr and David Shore. November 1938 Journal.
15. Frictional Resistance to the Flow of Air in Straight Ducts, by F. C. Houghten, J. B. Schmieler, J. A. Zalovcik and N. Ivanovic. December 1938 Journal.
16. Air Conditioning in Industry, by W. L. Fleisher, A. E. Stacey, Jr., F. C. Houghten and M. B. Ferderber (To be presented at the Annual Meeting, January 1939).
17. Cardiac Output, Peripheral Blood Flow, and Blood Volume Changes in Normal Individuals Subjected to Varying Environmental Temperatures, by F. K. Hick, R. W. Keeton, Nathaniel Glickman and H. C. Wall (To be presented at the Annual Meeting, January 1939). (Results of cooperative research at the College of Medicine, University of Illinois.)
18. Air Conditioning Requirements of an Operating Room and Recovery Ward, by F. C. Houghten and Dr. W. Leigh Cook (To be presented at the Annual Meeting, January 1939). (Results of cooperative research at the University of Pittsburgh.)
19. Heat Transfer in Storage Water Heaters, by D. W. Nelson and A. A. Rosenberg (To be presented at the Annual Meeting, January 1939). (Results of cooperative research at the University of Wisconsin.)
20. Air Filter Performance as Affected by Low Rate of Feed, Various Types of Carbon, Dust Particles Size and Density, by F. B. Rowley and R. C. Jordan (To be presented at the Annual Meeting, January 1939). (Results of cooperative research at the University of Minnesota.)
21. Reactions of Office Workers to Air Conditioning in South Texas, by A. J. Rummel, F. E. Giesecke, W. H. Badgett and A. T. Moses (To be presented at the Annual Meeting, January 1939). (Results of cooperative research at the Agricultural and Mechanical College of Texas.)

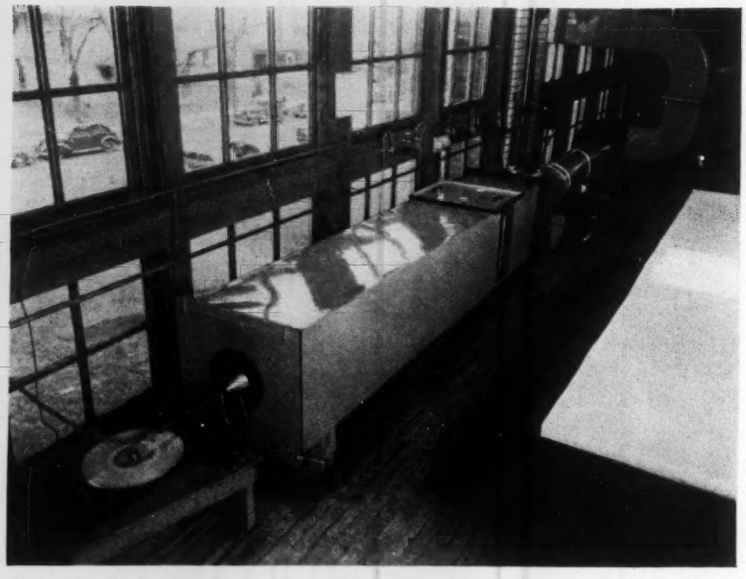

Fig. 5—Dust sampling device arranged with air filter test apparatus, University of Minnesota

A detailed presentation of the accomplishments of the Committee will be presented in a paper at the Annual Meeting in Pittsburgh, January 1939, and the following indicates results along the line of procedure set up in the Committee's original program.

1. A thorough study and analysis of available basic data from the records of the U. S. Weather Bureau and other sources, has indicated to what extent existing data are adequate for the purpose of heating and air conditioning design; and also, the causes of error in existing design weather data. It will *now* be possible to prepare a brief bibliography of available data.

2. The factors which apparently were not given full consideration in previous studies have been brought out in the course of analysis and should be given further consideration in future work. These are chiefly:

A. Wind velocities at lowest design dry-bulb temperatures in winter, and effect of solar radiance.

B. The possibility, duration, and effect of coincidental high dry-bulb and wet-bulb temperatures and wind velocities in summer.

C. Temperature differences between business and suburban districts, due to higher temperature conditions resulting in the former through trapping of solar heat in buildings and pavements, etc., and the difference between these temperatures and those taken at the local weather bureau station by duration of extremes and the time of their occurrence; i.e., day, night, morning or afternoon.

3. The work done under the auspices of the Committee in analyzing almost 3,000,000 temperature readings, has resulted in the adoption of methods of collecting and analyzing weather data from which uniform basis of future collection and analysis may be recommended.

4. Methods of obtaining data were considered and used as follows:

A. The U. S. Weather Bureau at Washington, D. C., made available to the Committee all of its records and also generously permitted the use of space in its office to employees of the Committee in abstracting temperature data from original records.

B. The Utilities with which there has been some discussion of the Committee's program, indicate a willingness to cooperate in carrying out the future program which is required to obtain data not now available.

The results of the Committee's work at the present time, include, besides the procedures outlined in the foregoing, certain valuable additions to existing design weather data which will be available next year. These data include not only corrections of existing design temperatures, but also quantitative data as to the number of hours and percentage of time during summer months in which various wet-bulb, dry-bulb, and dew-point temperatures occur, also wind velocities and hours of sunshine.

Possibly the most valued objective gained through the work of this Committee, to date, is the establishment of a basis upon which to proceed with future work that is required. While it is immediately apparent that an immense amount of time has been spent in making these data available, it is nevertheless, true that this work represents only a beginning of the ultimate project. The objectives of the future program of this Committee are as follows:

1. To establish uniform methods of obtaining and analyzing weather data upon which design conditions for any given locality may be based.

2. To quantitatively analyze existing weather data including dry- and wet-bulb temperatures, wind velocity, and sunshine, in a manner and over a sufficient period of years to show range and duration by months and seasons following the procedure already employed in obtaining some of the summer data.

3. To supplement the work being done by the U. S. Weather Bureau through obtaining those data which they do not have available. The chief deficiency is wet-bulb data which are only available for approximately four years in most localities. This supplemental work to consist of the taking of wet- and dry-bulb temperatures at a central point in each locality at the street level and at the average roof level for comparison with local U. S. Weather Bureau data, and in order also to determine any existing temperature differences between business and suburban sections and the influence of solar heat storage in massed pavements, buildings, etc.

4. To make available the information obtained in the foregoing to each locality through assembly, analysis, and distribution from one central point until such time as such work may be done by the Government as a part of its weather reporting program.

5. To recommend to the U. S. Government desired additions to and changes in the data being obtained through the weather bureau stations, and to support the required legislative effort as may be necessary to expand the activity of this bureau to include the reporting and dissemination of the data required in order to form a proper and adequate basis for design of heating and air conditioning systems.

Technical Advisory Committee 6
TRANSPORTATION AIR CONDITIONING

J. H. VAN ALSBURG, Chairman

W. I. Cantley
T. R. Crowder
A. G. Dixon
C. C. Elmes
L. H. Laffoley
E. A. Russell
W. E. Zieber

This Committee was continued for the year 1938 with the hope that active cooperation could be obtained from various railroad organizations to conduct extensive research work in this field. However, due to the inability of the Committee to obtain assistance from the railroad interests it was found inadvisable to initiate any studies this year, and consideration has been given to reviewing reports which have been previously published covering railroad air conditioning and preparing a report of recommendations for future research studies. The Committee has also given some consideration to preparing a research program on bus ventilation in the District of Columbia under the supervision of one of the Federal Agencies.

Technical Advisory Committee 7
RADIATION WITH GRAVITY AIR CIRCULATION

M. K. FAHNESTOCK, Chairman

B. C. Benson
H. F. Hutzel
J. P. Magos
J. W. McElgin
J. F. McIntire
D. W. Nelson
T. A. Novotney
W. A. Rowe

The work under this committee during the past year has been a continuation of a program which has been in progress for a number of years. The program may be divided into two parts: *First,* that which is being conducted in the warm wall test booth, and *Secondly,* that which may be conducted in the room heating testing plant.

Under the former the study of the size of the inlet and outlets of convector heater cabinets with reference to their effect upon the heat output or capacity of the units was completed, and the data are now being analyzed and prepared for presentation in a paper before the Society. This study was made with three distinct types of heating elements, and some twenty different combinations of inlets and outlets were tested in the cabinet used on each of the three heating elements. It is hoped that the

results will form the basis for designing convector cabinets having proper inlets and outlets for maximum heat output.

Under the second study the remodeling of the room heating testing plant has been practically completed and it will be placed in operation as soon as the calibration of the numerous thermocouples has been made. A thermal integrator and a globe thermometer are being constructed to determine the equivalent temperature of the environment when the test room is being heated by various types of radiators and convectors. These instruments will also be used in studying the radiation present in the environment.

The immediate program to be carried out in the test plant includes:

1. Tests to correlate the performance of conventional tubular steam radiators (sections on 2½-in. centers) in the new 15 ft x 18 ft x 8 ft 6 in. test room with their performance in the 9 ft x 11 ft x 9 ft test rooms which were in the old plant.
2. Tests to determine the performance of thin radiators free standing in the room under windows in exposed walls, and in recesses under windows in exposed walls.
3. Tests to determine the performance of several of the new lightweight or Junior size (sections on less than 2½-in. centers) of direct steam radiators, including their capacities and their distribution of heat in the room.

Since the room heating testing plant is now completed it is hoped that members of the committee, and the industry, will submit new problems adaptable to the facilities afforded by it.

Technical Advisory Committee 8
HEAT TRANSFER OF FINNED TUBES WITH FORCED AIR CIRCULATION

G. L. TUVE, Chairman

W. E. Heibel
H. F. Hutzel
R. F. Norris
R. H. Norris
C. H. Randolph
L. P. Saunders
C. F. Wood

Work under this Committee was continued at Case School of Applied Science and a paper was presented at the 1938 Semi-Annual Meeting. In this paper methods were reviewed which are available at the present time for selecting dehumidifying coils, and a new procedure was outlined which is referred to in the paper as the *humidity method*.

Further studies are being continued to determine the effect of refrigerant temperature on the performance of dehumidifying coils. Five sub-divisions of the general problem are covered in the present plan for experimental studies and correlation.

1. Variation of air-side surface coefficients of both dry and wet coils.
2. Effect of water velocities on the water-side cofficient of both refrigerating and heating coils, connected in counter-flow and in cross-flow.

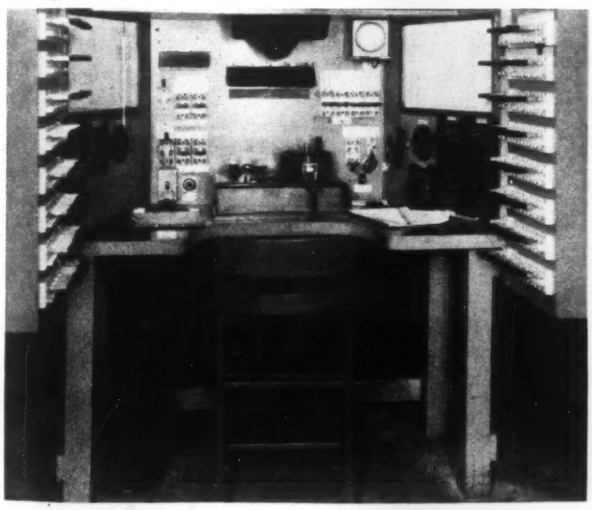

Fig. 6—Switchboard for 250 thermocouples located in remodeled room heating testing plant, University of Illinois

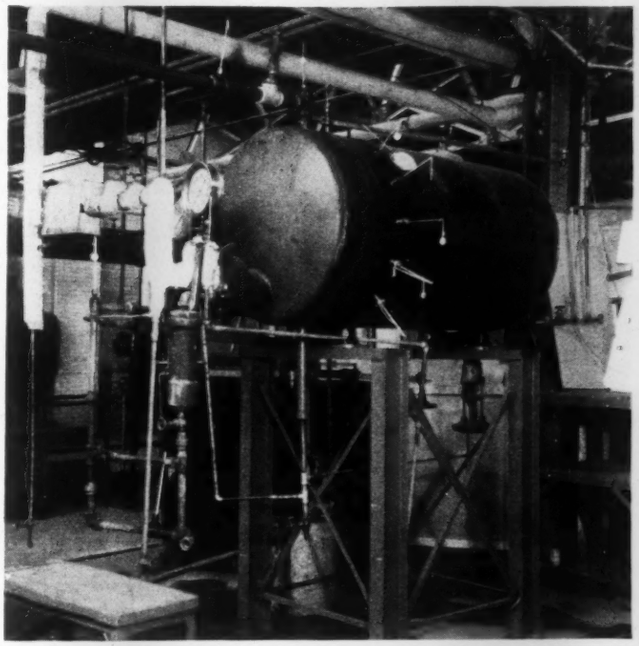

Fig. 7—Study of heat transfer in a water heater, University of Wisconsin

3. Improvement of methods for measuring refrigerant-side surface coefficients of direct-expansion coils.
4. Effect of coil depth or number of rows of tubes, and performance of very deep coils (6 to 10 rows).
5. Relation of heat transfer to air friction and air velocity.

The entire program is being directed towards the formulation of uniform practices which eventually can be used as a basis for a standard Society code for rating and selecting dehumidifying coils.

Technical Advisory Committee 9
COOLING LOAD IN SUMMER AIR CONDITIONING

J. H. WALKER, Chairman

C. M. Ashley
John Everetts, Jr.
F. H. Faust
A. E. Knapp
L. S. Morse
A. E. Stacey, Jr.
R. M. Strikeleather

This committee has been interested in the effect of heat transfer through walls and windows resulting from solar radiation, on the cooling load in summer air conditioning. So far, the committee has been interested in a few preliminary tests to determine the type of data needed and the analysis of results from various sources. From this work it has developed a comprehensive program for determining the needed information and methods of reporting it for design purposes. The work will be initiated as soon as the necessary budget is provided.

Technical Advisory Committee 10
SOLID FUELS

W. A. DANIELSON, Chairman

H. N. Eavenson
A. C. Fieldner
A. J. Johnson
Percy Nicholls
V. F. Parry
H. J. Rose
J. E. Schoen
L. E. Seeley
E. T. Selig
R. A. Sherman
R. Templeton Smith
C. Tasker

This Committee was organized shortly after the 1938 Annual Meeting in New York. It has been thought for some time that the Society should take a more active interest in fuels from the standpoint of the user. Coal and its solid products, and to a lesser extent wood, make up the major portion of the fuels used throughout the world and for that reason the Committee on Research recommended the initiation of a study

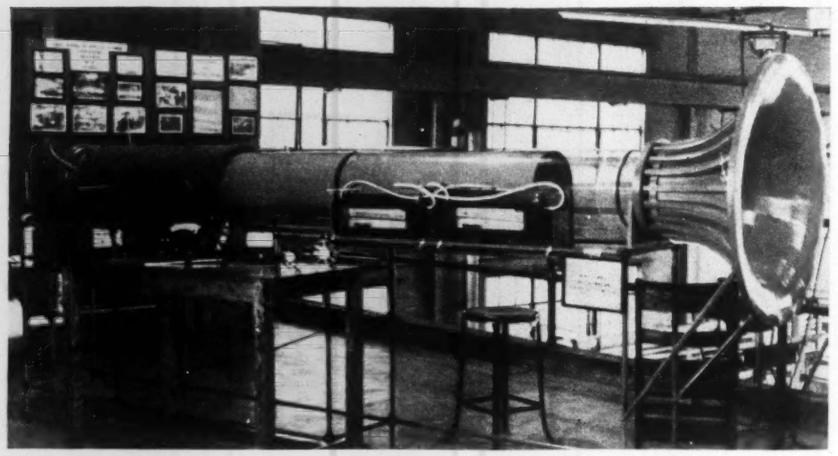

Fig. 8—Draw-through wind tunnel for calibrating air velocity meters with large bell mouth, transparent working section, orifice meter, and electrical thermo air meter, Case School of Applied Science

on that class of fuels. A comprehensive outline of the program that is now being studied has been prepared. Arrangements were made for a technical session at the 1939 Annual Meeting to be devoted to this subject.

Two sub-committees have been formed, one on anthracite headed by A. J. Johnson, and the other on bituminous coal and coke under the direction of R. A. Sherman. These Committees will determine methods of comparing performance of fuels and equipment under the various items of *consumer satisfaction*, will develop and propose minimum performance specifications, and will cooperate with other research agencies. A sub-committee on Bibliography consists of H. J. Rose, A. C. Fieldner and R. A. Sherman. This group has made plans to prepare short annotated bibliographies of recent articles on selected subjects relating to solid fuels and their utilization. Another sub-committee on Chimneys consists of the following personnel: A. J. Johnson, chairman, J. H. Billings, L. E. Moody, Stanley Morehouse, H. C. Plumber and G. B. Thom.

Technical Advisory Committee 11

SUMMER AIR CONDITIONING FOR RESIDENCES

M. K. FAHNESTOCK, Chairman

E. A. Brandt	E. D. Milener
John Everetts, Jr.	K. W. Miller
Elliott Harrington	R. E. Robillard
H. F. Hutzel	F. G. Sedgwick

J. H. Walker

The research work of this committee has been in progress continuously for the past seven years, and the results, not including those obtained during 1938, have appeared in seven technical papers presented before the Society and published in its JOURNAL and TRANSACTIONS. An eighth paper covering the work done during the summer of 1938 is being prepared. It covers the following items, some of which are a continuation of work started in 1937.

1. Tests to obtain additional information on the practicability of using a small capacity mechanical condensing unit in warm weather. Unfortunately, the cooling season of 1938, like that of 1937, did not afford any weather on which the outdoor temperature exceeded 95 F. However, by starting the cooling unit earlier in the day, when the indoor temperature reached 77 F, more desirable indoor conditions were maintained than in 1937.

2. Two series of tests were made for the purpose of determining the conditions resulting on both the first and second stories, when the conditioned air was all introduced on the second story. In one series of tests the cooling capacity of the plant was 18,000 Btu per hour and in the other it was 30,000 Btu per hour. The conditions maintained in the latter series of tests are to be compared with those attained in 1934 when the conditioned air from a plant having a capacity of 30,000 Btu per hour was introduced on both stories.

3. Using a cooling capacity of 30,000 Btu per hr, tests were conducted to obtain data on the rate at which the temperature and humidity could be reduced, after they had attained values materially above those conducive to comfort.

4. Using a Nicholls' heat-flow meter, data was obtained on the amount of heat passing through a section of the frame wall during entire 24-hour periods, where the studding space was filled with rock wool. These data are very interesting when compared with those obtained in 1937 on the same wall section with the studding spaces empty.

Technical Advisory Committee 12

AIR DISTRIBUTION AND AIR FRICTION

J. H. VAN ALSBURG, Chairman

S. H. Downs	L. G. Miller
M. K. Fahnestock	D. W. Nelson
F. J. Kurth	C. H. Randolph
R. D. Madison	Ernest Szekely

G. L. Tuve

Results from continued research extending over a period of three years, are being presented by the Laboratory in a paper at the 1939 Annual Meeting on frictional resistance to the flow of air in straight ducts. This paper presents two friction charts, one of which may be used for future research investigations, and the other for practical application work in the field. The studies on duct friction are not complete at the present time as further work is planned for investigations on rectangular ducts, elbows and numerous other fittings.

A comprehensive program for investigations in the field of air distribution have been planned for initiation at various cooperative institutions and the Laboratory. At the Case School of Applied Science a small wind tunnel has been equipped with a Thomas meter, orifice and pitot tube so tests can be conducted at very low velocities to determine instruments most suitable for recording low air velocities. At this institution studies are also being made on the behavior of air discharged from grilles into large and small unconfined spaces.

A project has been outlined at the University of Wisconsin to determine the most suitable types of fittings which may be used to produce equal air flow over the face of an opening, and also to determine the resistance characteristics for the several types of fittings. At the University of Illinois it has been planned that tests will be conducted in a cold room where the walls, ceilings and floors may be heated or cooled in order to determine the advantages of location of air outlet with specific regard to supply and return.

Technical Advisory Committee 13

HEAT REQUIREMENTS OF BUILDINGS

P. D. CLOSE, Chairman

W. H. Badgett	H. M. Hart
E. F. Dawson	H. H. Mather
W. H. Driscoll	F. B. Rowley
E. K. Campbell	R. J. J. Tennant

J. H. Walker

The activities of this Committee for the current year have included projects dealing with intermittent heating, heat losses

to the ground, selection of temperatures and wind velocities, and heat losses through top floor ceilings under pitched roofs.

Arrangements have been made for a study on intermittent heating to be conducted at the Agricultural and Mechanical College of Texas. Guion Hall, the College auditorium, is being used for this purpose and is heated by hot water from the central heating plant. A hot water flow meter has been installed as well as two pen recording thermometers in the flow and return mains to determine the quantity of heat supplied to the building. Recording and indicating thermometers have been placed throughout the building to measure air temperatures, and thermocouples have been placed in the exterior and interior walls, floor, ceiling and roof to determine temperature gradients through them. During periods of low outdoor temperature the building, with heat off, is opened and allowed to cool to as low a uniform temperature as possible; then closed and reheated to a uniform temperature. From these and other observed data, an effort is being made to determine the number of Btu per square foot of surface per degree temperature difference (indoor to outdoor) of the walls, floor and interior partitions for the construction of the building, and then for other typical building constructions, required to heat them to certain required temperatures in a given time. These results will be checked against theoretical calculations.

In connection with heat losses into the ground more reliable data are needed on the calculation of heat losses through basement floors into the ground. A study of this subject at the Research Laboratory is under consideration.

Present methods of calculating heat losses involve the selection of temperature and wind velocities which may have no relationship to each other and may not necessarily be the combination which will result in the maximum heat requirement. It is the opinion of some engineers that concurring combinations of temperature and wind velocity should be selected for computing heat losses, and such concurring combinations should be based on actual weather bureau records for each locality. An analytical study of this character for important cities in the United States is under consideration.

It is the practice in many cases to estimate the heat loss through top floor ceilings by assuming the attic temperature to be the mean between the inside and outside temperatures. In the case of attics with thick insulations between the ceiling joists, the attic temperature will ordinarily be only a few degrees above the outside temperatures rather than the mean between the inside and outside temperatures. Therefore, calculations based on the latter assumption are likely to be somewhat in error. A formula for calculating attic temperatures is proposed:

$$t_a = \frac{A_c U_c t_i + (A_r U_r + A_w U_w + A_g U_g)\, t_o}{A_r U_r + A_w U_w + A_g U_g + A_c U_c}$$

where:

t_a = attic temperature, degrees Fahrenheit.
t_i = inside temperature near top floor ceiling, degrees Fahrenheit.
t_o = outside temperature, degrees Fahrenheit.
A_c = Area of ceiling, square feet.
A_r = Area of roof, square feet.
A_w = Area of net vertical wall surface, square feet.
A_g = Area of glass, square feet.
U_c = Coefficient of transmission of ceiling, based on surface coefficient of 2.20 (upper surface).
U_r = Coefficient of transmission of roof, based on surface coefficient of 2.20 (lower surface).
U_w = Coefficient of transmission of vertical wall surface.
U_g = Coefficient of transmission of glass.

Example: Calculate the temperature in an unheated attic, assuming the following conditions: $t_i = 70$; $t_o = 10$; $A_c = 1000$; $A_r = 1200$; $A_w = 100$; $A_g = 10$; $U_r = 0.50$; $U_c = 0.40$; $U_w = 0.30$; $U_g = 1.13$.

Solution: Substituting these values in the previous formula:

$$t_a = \frac{(1000\times0.40\times70) + 10\,[(1200\times0.50) + (100\times0.30) + (10\times1.13)]}{(1200\times0.50) + (100\times0.30) + (10\times1.13) + (1000\times0.40)}$$

$$t_a = \frac{28{,}641}{1041} = 27.4 \text{ F.}$$

This formula does allow for attic infiltration, but this factor could readily be provided for, if deemed advisable, by introducing another term.

Technical Advisory Committee 14

AIR CONDITIONING REQUIREMENTS OF GLASS

M. L. CARR, Chairman

F. L. Bishop	Harold Perrine
A. N. Finn	W. C. Randall
S. O. Hall	L. T. Sherwood
E. H. Hobbie	J. T. Staples
R. A. Miller	C. Tasker
F. W. Parkinson	G. B. Watkins

F. C. Weinert

This Committee has been very active during the past year and has held two meetings, one at the time of the Annual Meeting and one at the time of the Semi-Annual Meeting. The Committee has maintained its own budget and has employed a research assistant at the Society Laboratory.

To date, no independent research has been carried on, but instead, the Committee has been interested in analyzing the results of research carried on in various branches of the industry. In this connection, two papers have been released for publication which are referred to in this report. The Committee has also developed a test specification for determining heat transfer through windows and glass block structures.

Technical Advisory Committee 15

INSULATION

W. A. DANIELSON, Chairman

E. A. Allcut	W. E. McMullen
R. E. Backstrom	R. T. Miller
H. C. Bates	W. T. Miller
Wharton Clay	E. R. Queer
H. C. Dickinson	T. S. Rodgers
J. D. Edwards	F. B. Rowley
W. V. Hukill	W. S. Steele
E. C. Lloyd	R. J. Tenkonohy
Paul McDermott	G. B. Wilkes

This Committee has considerable research work under investigation in a number of laboratories. The most extensive of these is at the University of Minnesota under the guidance of Prof. F. B. Rowley. The importance of the water vapor barrier on the warm side of an insulated enclosed space, and even in so-called uninsulated space where the humidity in the warm space is appreciably above that on the cooler side, has been definitely demonstrated. At the several meetings of the Committee, this situation was discussed at length and is at present the most important phase in the use of insulation. The Committee has also reviewed carefully the portion of THE GUIDE devoted to heat transmission and has made pertinent recommendations to the Guide Committee. This part of the work is being continued through a sub-committee. Basic studies on the relationship of structures to insulating values and evacuated spaces are being made under a cooperative agreement with the University of Toronto.

Technical Advisory Committee 16

SOUND CONTROL

J. S. PARKINSON, Chairman

C. M. Ashley	C. H. Randolph
G. F. Drake	J. P. Reis
A. M. Greene, Jr.	W. P. Roop
A. L. Kimball	A. E. Stacey, Jr.
V. O. Knudsen	G. T. Stanton
R. F. Norris	F. R. Watson

This Committee has devoted the larger part of its energies during the past year to the establishment of a test code for rating ventilating and air conditioning apparatus in terms of the noise generated by such apparatus. The object of such a code would be to provide a numerical decibel rating for each type of equipment which would (*a*) enable the prospective user or purchaser to compute the probable amount of noise which would be generated in a given location by this apparatus, and

(*b*) would enable such a purchaser to compare the merit of any given piece of equipment with other competitive apparatus. The establishment of such a code involves as a corollary the development of a testing technique.

A preliminary code was drawn up and submitted to the members of the Committee for their comments. When these had been received, the revised code was drafted and this has been resubmitted to the Committee members. The first study contemplated in the research on the acoustical problems, being conducted at Princeton University, will be an investigation of the testing techniques proposed in the apparatus test code.

The Committee has also assembled such information as was available on the acoustical behavior of ventilating and air conditioning equipment. As part of its activities, it undertook a review of the chapter on Sound Control in The GUIDE 1939.

Technical Advisory Committee 17
COOLING TOWERS, EVAPORATIVE CONDENSERS AND SPRAY PONDS

B. M. WOODS, Chairman

J. C. Albright	E. H. Kendall
S. C. Coey	S. R. Lewis
E. R. Goodrich	O. W. Ott
E. H. Hyde	E. H. Taze

Through a cooperative agreement with the Society investigations have been initiated at the University of California in Berkeley, to study four types of forced draft and atmospheric type cooling towers. Two atmospheric towers have been placed

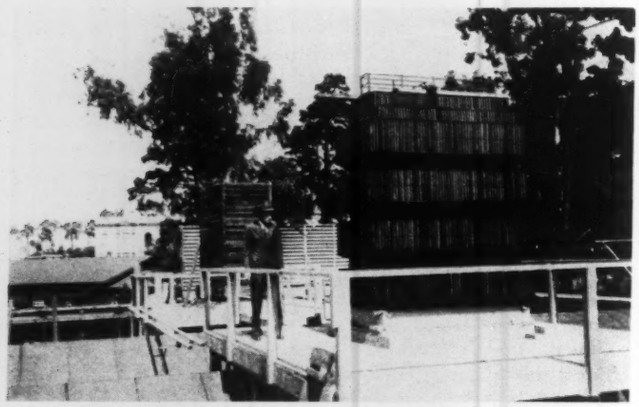

Fig. 9—Cooling tower investigations, University of California at Berkeley

on the roof of Hesse Hall on a rotating platform. The roof is shielded from wind by means of louvres. One of the forced convection towers employs *sheet* cooling and the other *drop* cooling.

High precision instruments have been developed and constructed for this project, and flow orifices for both air and water have been installed to record the results. Instruments which have been designed for this project include a portable hair hygrometer, a thermocouple hygrometer and a radiation meter. A pressure plate which possesses a high natural frequency and which will be used to record wind velocity variations is being designed for the study. An Assman psychrometer and a Tagliabue potentiometer are available for the project.

A technical report for publication by the Society is in preparation based on a complete set of performance test data which are now available on one of the towers. The nature of the packing in this tower is such as to cause the cooling of the water at the surface of water sheets (not drops). An analytical prediction of this tower yielded results which were in satisfactory agreement with the test data.

Data are being collected to establish a minimum rate of evaporation which will occur from a stationary, horizontal or vertical water surface into stationary air. Computations which will establish the rate of fall for water drops of different diameters are being made. From these results cooling rates may be predicted in any tower provided the drop size distribution is known. The drop size distribution in a tower will be obtained with the aid of high speed photography. These results should be of direct aid for tower design.

The Committee recognizes the importance of a study of evaporative condensers. It plans a review of the literature and status of design during the coming year from which an investigational program with laboratory experiments can be formulated. One member of the Committee is conducting experiments on water cooled roofs and has submitted a preliminary report. Work will be continued in the summer of 1939.

Technical Advisory Committee 18
PSYCHROMETRY

F. R. BICHOWSKY, Chairman

C. A. Bulkeley	F. G. Keyes
J. A. Goff	D. W. Nelson
A. M. Greene, Jr.	W. M. Sawdon

The general objective of this work is to prepare a thermodynamically consistent table of the properties of air and such charts based on this table as appear to be most useful. Dalton's Law of Mixtures has been universally employed in the properties of steam-air mixtures. A thermodynamic study of the properties of steam-air mixtures indicates that this assumption is not justifiable under the range of mixtures covered by the psychrometric chart and that therefore the standard tables for the properties of steam-air mixtures are seriously in error, the errors amounting to several degrees wet-bulb in some cases. For this reason the committee has undertaken an experimental determination of the deviations of steam-air mixtures from Dalton's Law, and has under consideration an experimental program covering development of a new type of wet-bulb instrument, calibration of this instrument, and direct determination of the heat of vaporization of water into air streams.

Technical Advisory Committee 19
CORROSION IN STEAM SYSTEMS

A. R. MUMFORD, Chairman

H. E. Adams	R. M. Palmer
J. F. Barkley	R. R. Seeber
W. H. Driscoll	F. N. Speller
T. J. Finnegan	C. M. Sterne

This group has carefully reviewed its program and decided to specialize for this year on one phase of the work.

The single phase selected for closer study is the determination of the amount of non-condensible gases which will dissolve in the condensate formed in a heating system at different rates of condensation when the steam contains a known amount of these non-condensible gases. This work is being conducted at the Michigan College of Mining and Technology. Another phase of the work which has been undertaken is a study of the operating cycle of typical hot-water heaters. This cycle includes a study of the variations in the rate of steam and water flow, condensate temperatures and related information. A progress report on the study of one such heater is expected to be ready for publication in the near future.

Interested manufacturers and steam-producing companies have been informed of a proposed project to determine the rate of corrosion caused by condensate formed in a partial pressure of carbon dioxide in the absence of oxygen. This project was proposed in order to determine whether the solution of iron by fresh condensate would buffer it sufficiently to render it non-corrosive shortly after it entered the return line system. It may not be possible to undertake this program at the present time.

hat later developments may change this preliminary conclusion because of the interest expressed by certain companies.

Technical Advisory Committee 20

CORROSION IN AIR CONDITIONING EQUIPMENT

A. E. STACEY, JR., Chairman

A. F. L. Anderson	**C. E. Lewis**
G. L. Cox	**R. M. Palmer**
M. L. Diver	**F. N. Speller**
W. R. Heath	**C. M. Sterne**

J. H. Young

At a meeting held in January 1938, it was decided that the best approach to studying corrosion in air conditioning equipment would be to locate samples of different materials with various protective coatings, both non-metallic and metallic, in apparatus located in different parts of the country. As these test samples had to be prepared by different individuals in several localities, the test samples were not available for testing during the 1938 operating season. It is the plan of the Committee to insert these samples in various equipment during the spring of 1939 in order that comparative results may be available for publication the latter part of the year.

The Committee has cooperated with 17 other technical societies in conferences intended to coordinate all of the corrosion activities in this country. Through the efforts of this group it is expected that all of the organizations actively engaged in corrosion may coordinate their efforts and thus avoid duplication.

RESEARCH FUND

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS
NEW YORK, N. Y.

For the Calendar Year Ended December 31, 1938

(From Report of Certified Public Accountants, Tusa & LaBella, New York, N. Y.)

STATEMENT OF INCOME AND EXPENSES

Income

CONTRIBUTIONS		
From General Fund—40% of Dues Collected	$16,955.88	
From Outside Sources—Per Schedule	4,885.00	$21,840.88
APPROPRIATIONS		
From General Fund		5,000.00
1938 EXPOSITION		9,673.56
INTEREST ON BANK DEPOSITS		60.91
		$36,575.35

Expenses

AT PITTSBURGH, PA.			
Salaries—Laboratory Staff	$12,969.50		
Salaries—Graduate Student Help	1,893.73		
Salaries—Office of Chairman	11.25		
Correlating Thermal Research	1,200.00		
Laboratory Supplies and Equipment	697.92		
Traveling	2,254.60		
Publicity and Promotion	692.50		
Meetings	289.97		
Office Supplies and Expenses	539.52		
Exhibits	752.54		
Printing	229.72	21,531.25	
COOPERATIVE RESEARCH			
General			
A. & M. College of Texas	$ 950.00		
Case School of Applied Science	700.00		
Princeton University	250.00		
University of California	600.00		
University of Illinois	600.00		
University of Minnesota	625.00		
University of Pittsburgh	375.00		
University of Toronto	500.00		
University of Wisconsin	300.00		
Weather Design Committee	300.00		
Medical			
University of Illinois	1,575.00	6,775.00	
OTHER RESEARCH			
Glass Study		2,012.30	
OTHER EXPENSES			
Weather Design Committee		200.00	30,518.55
EXCESS OF INCOME OVER EXPENSES			$ 6,056.80

BUDGET COMPARISON

	Actual	Budget Provision	Increases Decreases*
Income			
Balance from 1937 Committee—Cash in Pittsburgh and New York banks	$11,606.38	$11,606.38	.....
Dues—Current and prior years	16,955.88	15,000.00	$ 1,955.88
Special appropriations	5,000.00	5,000.00	.....
1938 exposition	9,673.56	3,500.00	6,173.56
Interest on savings account	60.91	.....	60.91
Contributions—General Research	1,675.00	.....	1,675.00
Contributions—Air distribution	1,600.00	.....	1,600.00
Contributions—Corrosion Steam Systems	550.00	.....	550.00
Contributions—Glass study	1,010.00	.....	1,010.00
Contributions—Intermittent heating	50.00	.....	50.00
	$48,181.73	$35,106.38	$13,075.35
Expenses			
Travel—Committee and laboratory staff	$ 2,254.60	$ 2,000.00	$ 254.60
Salaries—Laboratory staff	12,969.50	13,500.00	530.50*
Salaries—Student help	1,893.73	1,800.00	93.73
Salaries—Office of chairman	11.25	300.00	288.75*
Cooperative research—General	5,200.00	5,475.00	275.00*
Cooperative research—Medical	1,575.00	2,100.00	525.00*
Laboratory supplies and equipment	697.92	700.00	2.08*
Office supplies and equipment	539.52	500.00	39.52
Printing	229.72	250.00	20.28*
Exhibits	752.54	750.00	2.54
Correlating thermal research	1,200.00	1,200.00	.....
Promotion and Publicity	692.50	1,000.00	307.50*
Meetings	289.97	250.00	39.97
Contingencies	200.00	500.00	300.00*
	28,506.25	30,325.00	1,818.75*
Earmarked for glass study	2,012.30	3,411.93	1,399.63*
	30,518.55	33,736.93	3,218.38*
Balance	17,663.18	1,369.45	16,293.73
	$48,181.73	$35,106.38	$12,075.35

CORRELATING THERMAL RESEARCH

As a part of the efforts of the ASHVE Research Laboratory to correlate research in thermal engineering carried on by the many institutions engaged in such work, and to disseminate the published results of such studies together with other reports of progress in the field, and in order to make this information available to the membership of the Society, there is published monthly on this page a limited number of brief abstracts of articles which it is believed will be of interest to all concerned. For more complete lists address the Librarian, ASHVE Research Laboratory, U. S. Bureau of Mines Experiment Station, Pittsburgh, Pa.
F. C. Houghten, *Director.*

W. L. Fleisher, *Chairman*
COMMITTEE ON RESEARCH

Air Conditioning in Summer and Winter, by Richard E. Holmes. Published by McGraw-Hill Publishing Co., Ltd., London. A complete account of the main principles and methods employed in the several processes of a complete system of air conditioning.

•

Wall Construction for Air Conditioned Houses, and for Refrigerated Storages, by W. V. Hukill. Paper presented before the North Atlantic Section of the *American Society of Agricultural Engineers.* Extracts in *Heating and Ventilating,* Vol. 34, No. 11, Nov. 1938, p. 37.

•

The Thermal Insulation of Buildings: Part 1—General Principles. *The Institution of Heating and Ventilating Engineers,* Vol. 6, No. 69, Nov. 1938, pp. 485-492. General review of thermal insulation, with definitions of units of measure, method of calculation of air-to-air transmission coefficients. Thermal capacities of some building materials.

•

Insulated Glass. *The Architectural Forum,* Sept. 1938, pp. 18-22 and 46-50. A thorough discussion of single- and double-glazing, inside and outside temperatures. Diagrams of double-glazing installations, temperature gradients for single- and double-glazing. Relation of single- and double-glazing to condensation and frost temperatures inside of each glass.

•

Temperature Drop, A Neglected Factor Which Should Not Be Overlooked or Slighted, by B. L. Schwartz. *American Artisan,* Vol. 107, No. 12, Dec. 1938, pp. 37-39. Discussion of the temperature drop of the supply air from the point at which it leaves the heater to the outlet register in a warm air heating system.

•

Heat Required to Defrost Windshields, by Charles L. Hubbard. *Heating and Ventilating,* Vol. 34, No. 11, Nov. 1938, p. 55. Description of diffusion nozzle for defrosting windshields. Velocity and temperature of air necessary to keep glass clear.

•

Heat Production and Gaseous Metabolism of Young Male Chicks, by Barott and others. *The Journal of Nutrition,* Vol. 15, No. 2, Feb. 1938. Reprints available from Animal Nutrition Division, Bureau of Industry, National Agricultural Research Center, Beltsville, Md.

•

Nutritional Needs in Relation to Work, by R. Bonnardel, *Travail Humain,* Vol. 6, 1938, pp. 64-80. Review of the subject based on a great amount of international literature.

•

The Effect of Heat on the Blood Volume and Circulation, by Dr. H. C. Bazett. *Journal of the American Medical Association,* Vol. 111, No. 20, Nov. 1938, pp. 1841-1845. Change in blood volume may be attained by steady, moderate but maintained rise in environmental temperature, it is doubtful whether a fluctuating temperature can produce the same response. Changes in blood volume in both the upward and the downward direction are therefore controllable.

•

The Control of Indoor Environment by Air Conditioning With Special Reference to the Tropics, by G. P. Crowden and T. C. Angus. *The Institution of Heating and Ventilating Engineers,* Vol. 6, No. 69, Nov. 1938, pp. 442-484. Temperature records from India. Records were taken inside and outside a galvanized-iron hut, with varying amounts of insulation. Also temperature data taken inside and out of hut in antarctic.

•

Air Bacteria, by Arthur Cecil Stern. Series of three papers, *Heating and Ventilating,* Vol. 35, Nos. 10, 11, and 12, 1938. Oct. pp. 15-18, Nov. pp. 43-46, and Dec. pp. 40-43. Description of various types of micro-organisms found in the air, methods of counting bacteria and some data on number of bacteria at various locations in New York City. Some suggestions for improvements in air sanitation.

•

Planning Good Combustion, by C. A. Reed. *Coal Heat,* Vol. 34, No. 5, Nov. 1938, pp. 7-8. Requisites for good combustion in a power plant are a good foundation, ample and reliable equipment, intelligent supervision, efficient operation and a dependable fuel.

•

Process of Combustion in Stokers, by C. A. Barnes. *Coal Heat,* Vol. 34, No. 6, Dec. 1938, pp. 8-10. Discussion of combustion in fuel bed when stokers are used with coke and with coal.

•

The Transmission of Superheated Steam Over Long Distances, by Prof. L. F. C. A. Geneve. *The Institution of Mechanical Engineers,* London, *Proceedings,* Vol. 139, 1938, pp. 355-429. The paper aims to obtain as accurate a solution as possible to problems arising in the transmission of superheated steam over long distances for industrial heating and for power generation. Radiation losses reviewed. Effect of air currents on heat loss. Conditions during flow in a horizontal straight pipe, with perfect insulation are considered. Several new equations derived.

•

Comparative Fuel Costs for a Warm Floor Plenum System, by Everett S. Buck. *American Artisan,* Vol. 107, No. 11, Nov. 1938, pp. 54-56. Description of warm floor plenum system where warm air circulates in floor joist spaces.

•

The Radiation Experienced in Factories and Houses, by H. M. Vernon. *The Journal of Industrial Hygiene and Toxicology,* Vol. 19, No. 9, Nov. 1937, pp. 498-505. Report of tests made with a globe thermometer to determine the relation of globe thermometer readings with air temperature. In homes and most factories the two readings were in very close agreement, variation not over 1.6 F.

•

Air Conditioning Fires. Reports of 15 fires involving air conditioning installations. Published by the *National Fire Protection Association,* Boston, Mass., April 1938, pp. 325-328.

•

New Windowless Rayon Plant Air Conditioned. *Heating and Ventilating,* Vol. 35, No. 12, Dec. 1938, p. 25. Brief description of the new windowless, glass block factory building at Painesville, Ohio, built to accommodate production of custom-built rayon yarns. More than 370,000 glass blocks used in the 14 acre building.

North and South Texas Chapters Organized

The North Texas and South Texas Chapters will now be included among the organized Chapters of the Society, following meetings of Texas members in Houston on December 28, 1938 and in Dallas on December 29, 1938.

R. F. Taylor acted as temporary chairman and arranged for a dinner-meeting at the Rice Hotel, Houston, which was attended by 31 members and guests. The following were elected officers of the South Texas Chapter.

President—R. F. Taylor.
Vice-President—R. E. Chrone.
Secretary—W. H. Badgett.
Treasurer—I. E. Rowe.
Board of Governors—J. A. Kiesling, C. A. McKinney and R. W. Kotzebue.

The guest speaker of the evening was W. L. Fleisher, New York, chairman of the Society's Committee on Research, who addressed the members and guests on Research Finds Comfort and Efficiency Zones for Industrial Workers, and whose remarks were well received. He was introduced to the meeting by J. A. Kiesling, who has known Mr. Fleisher for over 10 years.

At the dinner-meeting in Dallas on December 29, officers were elected for the North Texas Chapter as follows:

President—C. L. Kribs, Jr.
Vice-President—H. K. Skinner.
Secretary—L. S. Gilbert.

The North Texas Chapter is to meet the second Monday of the month, and the remaining officers for the Board of Governors and the delegate to the Annual Meeting were scheduled for election at the January meeting.

Mr. Fleisher was also enthusiastically received at this gathering in Dallas, where he was again the speaker of the evening, and the Texas members express their appreciation for his visit.

Dr. Mills and J. H. Walker Address Western Michigan Members

January 9, 1939. Western Michigan Chapter met at the Elks Club, Grand Rapids, when dinner was served at 6:45 p.m. to 15 members and 28 guests.

In the absence of Pres. C. R. McConner, Vice-Pres. B. F. McLouth presided and called the meeting to order. After roll call by Secy. W. G. Schlichting, the minutes of the December meeting were read and approved.

Attention was called to the Conference on Air Conditioning at the University of Illinois, March 8 and 9.

Vice-President McLouth introduced the speaker of the evening, Dr. C. A. Mills, professor of experimental medicine, University of Cincinnati, who gave a splendid talk on Air Conditioning for Health. Dr. Mills illustrated the effect of climatic environment on health and disease, and traced its influence on the development of bodily vigor, resistance to illness and rate of growth among people in various parts of the world. He also showed how, through artificial control of indoor environment, much of this climatic dominance may be susceptible to human guidance through new developments in air conditioning.

A lively discussion followed Dr. Mills' talk, after which the meeting was adjourned at 10:00 p. m.

December 12, 1938. Forty-six members and guests attended the Western Michigan Chapter meeting at the Elks Club, Grand Rapids.

Pres. C. R. McConner called the meeting to order, and the minutes of the preceding meeting were read and approved.

O. D. Marshall introduced W. G. Boales, Detroit, who has been appointed general chairman of the Semi-Annual Meeting of the Society which is to be held at Mackinac Island in July 1939. Mr. Boales outlined the committee's proposed plans, including two cruises to and from the Island, originating in Chicago, Detroit, Cleveland and Buffalo.

After a short discussion of summer meeting plans President McConner then introduced the speaker of the evening, J. H. Walker, Detroit Edison Co., who gave a very interesting and instructive talk on Air Conditioning in a Glass Brick Building. Using slides to illustrate, he described the problems which were encountered, how they were taken care of, and described the general arrangement of the system which included approximately 80 zones. Mr. Walker also presented charts showing operation during the past cooling season.

After a brief discussion the meeting was adjourned at 9:30 p. m.

Meetings in Atlanta

January 3, 1939. The regular monthly meeting of the Atlanta Chapter was held at the Biltmore Hotel, and was called to order by Pres. C. L. Templin. Fifty members and guests were in attendance.

The chairmen of all Committees were called upon for reports of their various activities. The chairman of the Codes Committee, W. P. Sherman, submitted a detailed report in writing which proved to be most interesting and indicated the work of the Committee. Secy. T. T. Tucker was ordered to include this report in the minutes, and by unanimous acclaim all members acknowledged the assistance to this Committee of J. Wayne Moore, Jr. and Wynn Burton, non-members, who have taken a deep interest in codes. Mr. Sherman was particularly commended by Mr. Templin for his excellent work and continued activity in behalf of the Society.

C. T. Baker gave a most interesting synopsis of the recent meeting of the *American Society of Refrigerating Engineers*, which he reported to have been quite a large gathering, particularly inasmuch as this meeting was held in conjunction with the Power Show and the *ASME* meeting. One of the points of especial interest to members of the Society was the outline of Dr. Young's investigation in hospital air conditioning. He recommended that costs be reduced by more simple application of control and other equipment. He mentioned that it had been shown that there should be no recirculated air in operating or recovery rooms, but that a moot question remains in that no positive determination has been made as to actual conditions required in various parts of large hospitals.

Another subject covered at this meeting was chemical dehumidification, as well as the tendency toward raising the comfort zone, particularly in the summer, to higher temperatures. It was brought out at the meeting that this would lower the operating cost as well as initial cost, thereby creating a greater field and better satisfaction to present owners.

Because of wide interest in the subject of Air Distribution and Air Flow, Atlanta members were fortunate in having as their guest, F. J. Kurth. An interesting discussion followed Mr. Kurth's lecture, and Secretary Tucker extended the Chapter's appreciation to him, after which the meeting was adjourned.

December 13, 1938. The December meeting of Atlanta Chapter was also held at the Biltmore Hotel, and was attended by 17 members. After the minutes of the previous meeting were read, reports of the Officers and Committees were submitted. Pres. C. L. Templin and Secy. T. T. Tucker respectively were elected as delegate and alternate to the Annual Meeting in Pittsburgh, to represent the Atlanta Chapter.

At the completion of the Treasurer's report the Membership Committee reported several new members. The Secretary was directed upon motion duly made and seconded to inform the Codes Committee that the Refrigeration Service Engineers were planning on going before the various governmental authorities with the idea of establishing refrigeration and air conditioning codes. Also, that the desire of the meeting was that, if any codes were established, the ASHVE should take a very prominent part in the establishing of these codes.

Following the reports of the various Committees, W. J. McKinney, American Blower Corp., speaker of the evening was presented. Mr. McKinney addressed the members on the Applica-

tion of Fans and Blowers in the Air Conditioning Industry. He stressed the point of the practical application of theoretical problems which brought about an interesting discussion among the Atlanta members. After numerous questions were asked by the members and answered by Mr. McKinney, the meeting was adjourned.

Welding Discussed at Ontario Meeting

January 9, 1939. The regular meeting of Ontario Chapter was held at the Royal York Hotel, Toronto, at 6:30 p. m. with 55 members and guests present. Following dinner, it was moved by A. G. Ritchie and seconded by Thomas McDonald that the minutes be accepted as written.

M. W. Shears, chairman of the Code Committee, asked for adoption of the Warm Air Heating Code as proposed. It was moved by M. S. Woollard and seconded by D. I. Paul that the infiltration factors in this code agree with the infiltration factors in the Steam and Hot Water Heating Code recently adopted by the chapter. It was moved by A. H. Hills and seconded by L. K. Hughes that the Warm Air Heating Code be accepted with the amendment suggested and this motion was carried.

Pres. H. B. Jenney urged all members to attend the Pittsburgh Annual Meeting of the Society and J. H. Fox, chairman of the On to Pittsburgh Committee, spoke of arrangements being made for members attending the meeting.

Mr. Fox introduced the principal speaker of the evening, W. A. Duncan, who spoke on Modern Oxy-acetylene Welding of Piping. Mr. Duncan also showed a movie reel on welding. Following an interesting discussion, A. T. Jones thanked the speaker for his instructive address on behalf of the Chapter and the meeting was adjourned.

Research Studies Reported at Southern California Meetings

January 3, 1939. A meeting of Southern California Chapter was held at the Colonial Banquet Room in downtown Los Angeles and was preceded by dinner. A short business session was conducted by Pres. H. M. Hendrickson, and 94 members and guests were present.

W. L. Fleisher, New York, chairman of the Committee on Research of the ASHVE, was introduced as the speaker of the evening and discussed in general the work of the committee and more specifically the research work being undertaken with regard to human comfort and efficiency in industry. According to Secy. A. J. Hess this talk was extremely interesting to all those present and contained a wealth of information which will be used by many of those present to supplement the work in which they are engaged in the design of air conditioning systems.

An open discussion followed during which Mr. Fleisher answered the questions of members in a very satisfactory manner.

December 16, 1938. Southern California Chapter met with 54 members and guests present, all of whom enjoyed the dinner which preceded the technical session. Routine business was disposed of and the speakers of the evening were introduced. The discussion of research studies was led by Prof. L. M. K. Boelter, University of California at Berkeley, who was assisted by Prof. W. E. Mason, University of California at Los Angeles, and two students of the Berkeley division, Messrs. Hilleger and Brown.

The discussion related to cooperative research concerning cooling towers and spray ponds, and it was interesting to the members of the Chapter to hear of the progress of this work. To most of those present, it was a surprise to learn that many of the instruments used in the tests had to be constructed and worked out and calibrated before proceeding, since there were no devices available for making the type of test required in this research work.

It was also noted that for certain types of towers, some progress has been made and certain preliminary conclusions can be drawn regarding the results to be expected of these devices. The information gleaned from preliminary experiments on two cooling towers is being used to predict the operation of future experiments in order to see how the information now available from research fits in with practical application. The Southern California Chapter believes that this research is of double value because of the fact that those in charge have realized that, while the scientific information is necessary, it must be correlated with formulas and rules which can be applied to practical applications, and that this work is being carried on simultaneously with the research studies.

After the cooling tower discussion, Mr. Colesworthy, Westinghouse Electric & Manufacturing Co., presented a talk on the Precipitron, which is an electrostatic precipitator or filter. This discussion was very interesting and the demonstration of the Precipitron was enjoyed by the Chapter, according to Secy. A. J. Hess.

Air Diffusion and Heat Transfer Subjects of Cleveland Chapter

January 9, 1939. Northern Ohio Chapter met at the Cleveland Club with 32 present at dinner and 54 at the meeting which followed. In the absence of Pres. J. P. Jones, Vice-Pres. D. L. Taze presided.

Secy. C. M. H. Kaercher read the minutes of the previous meeting which were accepted, and he also reported on the membership status of the Chapter.

A report was given by Treas. E. W. Gray.

C. F. Eveleth, chairman of the Publication Committee, gave a brief report, calling attention to an article on duct work and a book by Charles A. Fuller on Air Conditioning, which he considered very comprehensive.

V. B. Kofoed, of the Entertainment Committee, outlined tentative plans for the social meeting in February, which would consist of dinner at 8:30 at the Shaker Tavern to be followed by dancing. The date of February 11 was chosen and Mr. Kofoed urged that reservations be sent in as early as possible.

P. D. Gayman, chairman of the Program Committee, announced that on March 13 the speaker would be Prof. G. L. Larson, University of Wisconsin, Madison, Wis.

L. S. Ries of the Membership Committee advised that this group was now well organized and hoped to show some tangible results of their work at the next business meeting.

In the absence of L. T. Avery, chairman of the Committee on Arrangements for the 1940 Annual Meeting, Philip Cohen reported and read the appointments to various committees for preparatory work.

W. R. Beach spoke of his willingness to assist Cleveland members in arranging for their transportation to the Annual Meeting in Pittsburgh and W. R. Rhoton spoke of the benefits derived from attending Society meetings and pointed out the unusual opportunity afforded because of the short distance to Pittsburgh.

The meeting was then turned over to the Program Committee, who introduced as the guest speaker, F. J. Kurth, Anemostat Corporation. Mr. Kurth gave an interesting talk on Air Diffusion from Ceiling Outlets, followed by a demonstration. The members expressed their appreciation to the speaker for his instructive and interesting presentation by a rising vote of thanks.

December 12, 1938. Vice-Pres. D. L. Taze presided at a meeting of Northern Ohio Chapter in the Cleveland Club with 27 members present for dinner and 72 members at the meeting.

The minutes of the November meeting were read and several communications were presented by Secy. C. M. H. Kaercher concerning the Annual Meeting of the Society at Pittsburgh, a radio broadcast, and the election of a representative to the Nominating Committee.

Treas. E. W. Gray reported receipts and disbursements and the current balance.

C. F. Eveleth, chairman of the Publication Committee, gave a

complete review of interesting articles in current trade publications.

F. A. Kitchen announced that it was the recommendation of the Entertainment Committee that the social meeting be held in February instead of January, because of conflicting engagements. The Committee suggested a dinner followed by dancing and their recommendations were accepted.

J. A. Schurman, Jr., chairman of the Standards Committee, reported a communication from the *Cleveland Association of Consulting Engineers* regarding the suggested Code of Air Conditioning, and after considerable discussion the Committee was instructed to re-submit the Code to them with all references to the sponsorship omitted.

L. T. Avery reported for the Transportation Committee regarding arrangements for attending the Pittsburgh meeting. He urged that as many members as possible take their wives to the Annual Meeting so that the ladies might get better acquainted and might observe the arrangements made for entertainment as a guide for their own preparations for the 1940 meeting in Cleveland.

Mr. Taze called for nominations for the selection of a representative on the Society's Nominating Committee. Prof. C. A. McKeeman was nominated and in the absence of further nominations, a motion was made and carried that Secretary Kaercher be instructed to cast a unanimous ballot for Professor McKeeman as the representative of Northern Ohio Chapter on the Society's Nominating Committee.

On motion of Mr. Kitchen, Mr. Taze was nominated as alternate and the Secretary was likewise instructed to cast a ballot for Mr. Taze.

Nominations were then called for the Chapter delegate to the Annual Meeting in Pittsburgh. It was suggested by Mr. Cohen that the delegate be one of the newer members and Secretary Kaercher was then chosen unanimously as the delegate.

The meeting was then turned over to the Program Committee, who introduced William Goodman, Trane Co., who gave an instructive talk on the subject of Heat Transfer by the Use of Extended Surface, with particular reference to cooling coils.

After an open discussion which indicated considerable interest in the subject, the meeting was adjourned.

Iowa-Nebraska Meets at Omaha and Des Moines

January 10, 1939. The meeting of Iowa-Nebraska Chapter was held at the Fontenelle Hotel, Omaha, and was called to order by Pres. W. R. White. Minutes of the previous meeting and the treasurer's report were read and approved.

Guests were introduced by various members of the Chapter and were cordially welcomed by President White. The Chapter dispensed with formal business so that the speaker would have sufficient time and so that adjournment could take place at a reasonable hour for those members coming from Des Moines and other distant points.

R. E. Hattis, consulting engineer, Chicago, was introduced by Secy. Henry Kleinkauf. Mr. Hattis gave an excellent lecture illustrated with slides on The Air Conditioning of a Windowless Building. At the close of Mr. Hattis' address, there was a lively discussion and it was felt by the members present that this type of talk was extremely interesting.

December 13, 1938. Pres. W. R. White presided at a meeting of Iowa-Nebraska Chapter held at the Savery Hotel, Des Moines. Minutes of previous meetings were read, in addition to a telegram from A. F. Nass of Pittsburgh Chapter with reference to the Society's Annual Meeting. Secretary Henry Kleinkauf reported for the Membership Committee and T. R. Johnson of the Meetings Committee advised that dates were well scheduled until the end of the year.

President White appointed the following Legislative Committee: Prof. R. A. Norman, chairman, (one year); F. R. Vaughn (two years); and Henry Kleinkauf (three years).

Nominations for the Nominating Committee were in order and it was moved and seconded that the following nominees be unanimously elected: W. V. Hagan, R. F. Winterbottom, F. E. Triggs, F. L. D. Banner, and M. S. Tapley.

Nominations were received for delegate to the Society's Annual Meeting. J. C. Knox nominated T. R. Johnson, who was seconded by R. F. Winterbottom. Secretary Kleinkauf nominated President White, who was seconded by A. L. Walters. Mr. Johnson withdrew in favor of Mr. White. It was moved by Mr. Walters, seconded by M. L. Todd and carried that Mr. White be unanimously elected delegate. It was further moved by Mr. Walters and Mr. Todd that Mr. Johnson be alternate and this motion was carried. President White thanked the Chapter for their consideration in electing him as their delegate.

After a short recess, the meeting reconvened and F. W. Willis, Tuttle & Bailey, Inc., gave a lecture on Performance of Air Conditioning Grilles. The talk and accompanying movie illustrations were well received and resulted in a good deal of comment.

Pittsburgh Chapter Interested in Fire Underwriters' Views

January 9, 1939. Pres. R. A. Miller called the meeting of Pittsburgh Chapter to order at 7:45 p. m. in the private dining room of Stouffers Restaurant with an attendance of 46 members and guests. The minutes of the December meeting were read and approved.

The report of the treasurer was read by Secy. T. F. Rockwell and J. F. Collins, Jr., general chairman of the Committee on Arrangements for the 1939 Annual Meeting of the Society, called on the following committee chairmen to report on their work: R. B. Stanger—Entertainment; A. F. Nass—Attendance; J. E. Frazier—Reception; E. C. Smyers—Banquet.

President Miller asked all committees appointed for 1938 to continue their work until after the Annual Meeting and he appointed E. C. Smyers, chairman, E. H. Riesmeyer, Jr. and J. F. Collins, Jr. as an Auditing Committee.

W. K. Estep, manager, *Middle Department Rating Association*, was introduced by R. J. J. Tennant and spoke on A Fire Underwriter's Views on Heating and Air Conditioning Systems. The speaker devoted the introduction of his paper to explaining the work of a rating association and the work of the *National Fire Protection Association* and the Underwriters Laboratories. Then Mr. Estep discussed the effect of the installation of heating and air conditioning systems on the fire hazard within buildings. Emphasis was placed on the propagation of fire within the duct because of dust and the possibility of smoke from fires in adjoining buildings entering through improperly located outside air intakes. In conclusion, Mr. Estep pointed out that underwriters were particularly concerned by the piercing of fire divisions within buildings by ducts, such practice virtually destroying the value of the fire division in their opinion.

A rising vote of thanks was tendered to Mr. Estep after a question period which followed his address.

Annual Reunion at Buffalo

December 20, 1938. The December meeting of the Western New York Chapter was the occasion of the annual Christmas party held at the University Club in Buffalo, with an attendance of 41 members and guests. The routine business was postponed until the January meeting.

In preparation for the Annual Meeting of the Society in Pittsburgh, the Chapter voted to appoint J. J. Landers as its representative and L. P. Saunders as alternate to attend this meeting the latter part of January. C. W. Farrar outlined the annual meeting program and urged a large attendance from the Western New York Chapter. M. C. Beman spoke of the opportunity of those attending the meeting to visit the ASHVE Research Laboratory.

J. J. Landers, president of the Chapter, then announced the

new officers of the Buffalo Air Conditioning Council, the majority of whom are members of the Society, and introduced those of the new officers present, including Joseph Davis, Walter Davis, Sherman Strause and Harry Schafer.

C. A. Gifford announced that Mr. Saunders, who was appointed as alternate to attend the Annual Meeting, was scheduled as speaker at the January meeting on the subject, The Automobile Engineer Looks at Heating and Ventilating.

The meeting was then turned over to D. J. Mahoney, who read several telegrams, after which various prizes were awarded.

Prof. Wells Addresses Philadelphia Chapter

December 8, 1938. Philadelphia Chapter met at the Engineers Club, and the minutes of the previous meeting and the treasurer's report were read and approved.

Edwin Elliot reported two new members for the Philadelphia Chapter, namely W. J. Searle and C. A. Bulkeley.

The Chapter's annual dinner meeting in January at Kuglers was announced by R. F. Hunger.

L. P. Hynes spoke of the Society's Annual Meeting in Pittsburgh, January 23-26, and called attention to the outstanding papers on the meeting program.

Pres. H. H. Erickson introduced Prof. W. F. Wells, who presented an interesting paper on Sanitary Ventilation. This was followed by a lively and constructive discussion, before the meeting was adjourned at 10:15 p. m.

Air Distribution and Diffusion Topic of Massachusetts Meeting

January 17, 1939. Ninety members and guests of Massachusetts Chapter were present at a meeting held at Massachusetts Institute of Technology, Boston, with Pres. James Holt presiding.

A reminder announcement was made of the Society's Annual Meeting in Pittsburgh, January 23-26.

The speaker of the evening was F. J. Kurth, Anemostat Corp. of America, and a member of the Society's Research Technical Advisory Committee on Air Distribution and Air Friction. Mr. Kurth spoke on the general topic of Air Distribution and Diffusion and the principles involved were demonstrated by the use of smoke in a model apparatus.

According to Secy. H. C. Moore, this proved to be an interesting meeting as manifested by the number of questions asked at the close of the talk and by the large attendance.

Research at Illinois Medical School Reported

December 12, 1938. The December meeting of Illinois Chapter was called to order at 7:45 p. m. at the Merchants & Manufacturers Club, Chicago, with 84 members and guests attending.

Secy. M. W. Bishop read the minutes of the November meeting, which were approved. I. E. Brooke introduced a new member, W. M. Woll. Reports on the activities of their committees were made by E. M. Mittendorff of the Finance Committee and V. L. Sherman of the Meetings Committee.

Pres. J. R. Vernon called on R. E. Hattis to introduce the speakers. After brief introductory remarks, Mr. Hattis presented to the meeting Dr. R. W. Keeton, head of the Department of Medicine, University of Illinois, and Dr. F. K. Hick, also of this department.

Speaking of the cooperative research undertaken by the ASHVE and the University of Illinois Department of Medicine, the speakers told of the environmental factors in air conditioning as regards human heat mechanisms. They described the generation of heat by the muscles, liver, viscera and heart; its transfer by blood flow to the body surface and the lungs; its liberation through latent and sensible means; and the physiological reaction of unbalanced heat losses.

The talks were detailed and complete and the results obtained in many of the experiments were fully illustrated by slides. Both the speakers held the attention of their audience throughout, as was attested by the numerous questions and discussion which followed the talks. Dr. E. V. Hill, J. J. Aeberly and R. E. Hattis were among those taking part in the discussion.

Dr. A. A. Adler Dies Suddenly

Friends of Dr. A. A. Adler were greatly shocked and saddened by his sudden death on January 13, 1939 resulting from a heart attack, with which he was stricken in the Journal Square Station of the Hudson Tubes while on his way from his home at 35 Stewart Ave., Arlington, N. J. to lecture at New York University. Dr. Adler was well known as a consulting engineer, educator and author.

Born at Mewe, Germany, on November 27, 1881, Dr. Adler came to this country at the age of three months. He received the degree of Bachelor of Science from Cooper Union in 1903, Mechanical Engineer from Polytechnic Institute in 1909, and Doctor of Science from New York University in 1915. He also had done graduate work at Columbia University.

At various times Dr. Adler worked for Westinghouse, Church, Kerr & Co., W. S. Barstow & Co., and the Pennsylvania Railroad. Joining the Polytechnic Institute faculty in 1910 as an instructor, he was made an assistant professor of mechanical engineering, holding that post until 1920. As a consulting engineer later he specialized in power and industrial plant design and the application of science to technical problems.

After leaving Polytechnic, Dr. Adler continued to lecture there as a professor, as well as lecturing at New York University. He was awarded his doctorate in science for research work on the Surface Tension of Liquid Mixtures at Various Temperatures. He was the author of Theory of Engineering Drawing and Principles of Parallel Projecting Line Drawing, both standard engineering textbooks.

Dr. Adler was elected a Member of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS in 1921 and in 1925 he was president of the New York Chapter of the Society. His loyalty and interest were expressed in his willingness to cooperate to further the activities of the Society, rendering great service, and at the time of his death he was a member of the Committee on Admission and Advancement. He was also a former chairman of the Metropolitan Section of the *American Society of Mechanical Engineers.*

Funeral services were held for Dr. Adler in the Cook Funeral Chapel at 8:00 p. m., Jan. 17, and officers of the Society and the New York Chapter attended as well as many members. Interment was in Woodlawn Cemetery.

Surviving are his widow, Mrs. Kathryn Kraft Adler, three brothers, and a sister, to whom the Officers and Council of the ASHVE extend their sincere sympathy.

John McKinley Dies in Texas

John McKinley, recently elected to membership in the Society, died as a result of a heart attack, December 22, 1938, which he suffered while at work in his office earlier in the month. He was born on May 3, 1891 at Macon, Ga.

Mr. McKinley, a thoroughly experienced refrigeration engineer, was both well known and well thought of in the refrigeration industry, having been in that field for over 20 years. Before founding the McKinley Refrigeration Supply Co., Fort Worth, in 1936, he was manager of the Dallas branch of the General Refrigeration Sales Co., which position he held for seven years. At the time of his death he was also secretary of the *Fort Worth Air Conditioning Association.*

The Officers and Council of the Society extend their sincere sympathy to his widow, Mrs. Pearle M. McKinley and to his son, Carrol B., also a member of the Society, and to his family, who survive.

CANDIDATES FOR MEMBERSHIP

The Constitution of the Society, as now amended, requires the following mode of procedure in voting on applicants for membership in the Society. All applications for membership are to be sent to the Secretary and the names of applicants and their references shall be printed in the next issue of the JOURNAL of the Society or sent to the members in other approved manner as ordered by the Council. When replies are received from references, the Candidate's application shall be submitted to and acted upon by the Committee on Admission and Advancement as soon as possible.

When the Committee on Admission and Advancement has acted favorably upon a Candidate's application and assigned his grade, the Council shall vote upon the election of the proposed Candidate for membership by letter ballot. During the past month 42 applications for membership have been received and the names of these men and their sponsors are published in the following list.

Members are requested to scrutinize the list with care. The Committee on Admission and Advancement, and in turn, the Council, urge the members to assume their share of responsibility of receiving these candidates into membership by advising the Secretary promptly of any whose eligibility for membership is in any way questioned.

All correspondence in regard to such matters is strictly confidential, and is solely for the good of the Society, which it is the duty of every member to promote.

Unless objection is made by some member by February 15, 1939, these candidates will be balloted upon by the Council. Those elected to membership will be notified by the Secretary immediately after election.

CANDIDATES	REFERENCES	
	Proposers	*Seconders*
ADAMS, F. L., Htg. & Air Cond. Engr., Public Service Co. of Colo., Denver, Colo.	J. E. McNevin L. R. O'Rear	A. F. Davis D. J. McQuaid
ADDINGTON, H. M., Asst. Engr., U. S. Veteran's Administration, Washington, D. C.	R. H. Feltwell S. P. Eagleton	Glegge Thomas C. N. Douglass (*Non-Member*)
ARCHAMBAULT, J. A., Htg. Sales Office Mgr., C. A. Dunham Co., Ltd., Toronto, Ont., Can.	F. A. Hamlet Leo Garneau	A. E. Watts C. W. Johnson
ARONSON, H. H., Sales Engr., Premier Furnace Co., Chicago, Ill. (*Reinstatement & Advancement*)	Henry Mathis H. F. Maier	R. E. Deming G. W. Smith
BARTH, J. W., Student, Thermo Air Cond. Inst., Los Angeles, Calif.	E. H. Kendall A. J. Hess	H. B. Lauer Harrold English
BERTRAND, G. F., Mgr., Universal Air Cond. Corp., Philadelphia, Pa.	E. H. Dafter W. L. Yerkes	W. A. Bornemann M. E. Barnard
BIGGERS, R. H., Mfrs. Agent, Detroit, Mich.	A. E. Knibb L. L. McConachie	G. L. Davis Harold Clark
BLACK, J. M., Student, Case School of Applied Science, Cleveland, Ohio	G. L. Tuve C. A. McKeeman	D. K. Wright F. H. Vose (*ASME*)
BLAYNEY, W. R., Secy.-Treas. & Partner, W. B. Graves Htg. Co., Chicago, Ill.	A. O. May C. W. Johnson	J. F. Hale E. P. Heckel
BREX, I. E., Asst. Secy. & Treas., Brex & Bieler, Inc., Brooklyn, N. Y.	F. W. Wills J. H. Van Alsburg	A. W. Glessner (*Non-Member*) C. E. Glessner (*Non-Member*)
DAVIS, R. J., Chief Instructor, Thermo Air Cond. Inst., Inc., Los Angeles, Calif. (*Reinstatement*)	S. D. Peterson W. W. Cox	W. E. Beggs P. M. O'Connell
DEMING, R. E., Htg. Engr., Premier Furnace Co., Dowagiac, Mich.	J. S. Cunningham T. W. Torr	R. W. Wilson H. A. Brinker
GEIGER, R. L., Engr. & Draftsman, J. P. Jones, Cary & Millar, Cleveland, Ohio.	D. L. Taze Walter Baggaley	J. P. Jones E. B. Cary
GOOD, C. S., Student, Carnegie Inst. of Tech., Pittsburgh, Pa.	C. M. Humphreys T. F. Rockwell	H. A. Beighel F. C. McIntosh
GRAHAM, J. B., Student, Carnegie Inst. of Tech., Pittsburgh, Pa.	C. M. Humphreys T. F. Rockwell	P. A. Edwards Leighton Orr
HALL, C. J., Htg. & Vtg. Engr., American Radiator Co., New York, N. Y.	R. E. Daly C. W. Brabbée	H. W. Fiedler Bernard Goerg
HOFFMAN, HARRY, Br. Mgr., Johnson Service Co., Greensboro, N. C.	H. H. Hill E. H. Brandt, Jr.	M. F. Rather F. E. W. Beebe
IVERSTROM, CARL, Htg. & Vtg. Engr., WPA, New York, N. Y.	E. B. Fitzpatrick (*Non-Member*) R. L. Fox (*Non-Member*)	A. W. Keller (*ASME*) E. C. Sherwood (*Non-Member*)
JACOBI, B. A., Mgr., Fan & Blower Div., Air Conditioning Utilities, Inc., New York, N. Y. (*Reinstatement and Advancement*)	H. W. Fiedler J. G. Foster	C. M. Humphreys T. F. Rockwell
JOHNS, C. F., Chief Engr., The Enterprise Foundry Co., Ltd., Sackville, N. B., Can. (*Reinstatement*)	F. L. West (*E.I.C.*) H. W. McKiel (*E.I.C.*)	Frank Binns (*E.I.C.*) H. W. Read (*E.I.C.*)
JOHNSTON, M. T., Mech. Engr., Walgreen Co., Chicago, Ill.	G. W. Lindsay, Jr. T. F. McCarthy	O. J. Greenwood J. R. Vernon
LEWIS, W. W., Mgr., Htg. & Air Cond. Dept., Beeson Hardware Co., High Point, N. C.	J. E. Maynard L. G. Miller	C. W. Nessell V. B. Kofoed
LIEBERMAN, M. S., Student, Carnegie Inst. of Technology, Pittsburgh, Pa.	C. M. Humphreys T. F. Rockwell	P. A. Edwards F. C. McIntosh
LIVERMORE, J. N., Engr., Detroit Edison Co., Detroit, Mich.	J. H. Walker G. D. Winans	E. E. Dubry G. H. Tuttle
MALIN, B. S., Mech. Engr. (Air Cond. & Ventilation) U. S. Dept. of Agriculture, Washington, D. C.	W. R. Lockhart E. V. Fineran	A. E. Stack S. P. Eagleton